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Aircraft Pneudraulic Systems Mechanic

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Pneudraulic Systems

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Preface

IT CAN BE SAID that troubleshooting is largely a matter of logic sprinkled with a little wisdom, judgment, and experience. This volume is designed to assist you in acquiring this experience and good judgment by reviewing certain technical information, such as operational characteristics of pneudraulic systems, common system malfunctions and remedies, and the systematic procedures for locating and correcting these malfunctions.

The systems and components discussed in this volume are representative of those with which you, as the pneudraulics specialist, will likely be working. For instance, the types of selector valves and actuators discussed here are representative of the units in any pneudraulic system. In parts of the discussion, fairly exact values such as tolerances, pressures, temperatures, weights and inches are given to provide realism in the coverage. However, these values should not be taken literally since they have been known to change. Therefore, when actually performing the maintenance procedures discussed, you should consult the applicable technical order for the latest information and exact values to be used.

Foldouts 1 through 12 are bound separately as a supplement.

Code numbers appearing on figures are for preparing agency identification only.

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Contents

Pneudraulic Power Systems

A PNEUDRAULIC power system furnishes the pressures to operate such systems as the landing gear, nose wheel steering, brakes, flight controls, etc. Subsequent chapters of this volume contain detailed information concerning the constructional features and operation of these systems. What part do you play in maintaining a pneudraulic power system? You make scheduled inspections and operational checks, and you service such items as reservoirs and accumulators. Besides this, as a pneudraulic specialist, you will be called upon to troubleshoot various systems. You must see that the trouble is corrected in the minimum length of time. To accomplish this, the specialist must be highly skilled in the art of troubleshooting. Much of this skill comes from knowledge acquired through experience.

1-1. Operation and Troubleshooting

In this section, we will discuss a specific pneudraulic power system found on large aircraft. We show you how they function and the purpose of the individual units. We also examine the types of units used in various aircraft hydraulic power systems. In order to troubleshoot a system, you must know how it works; so we shall consider the complete operation of the system. The discussion will cover the electrical operation of various units as well as the fluid flow from each component. Then, we will consider some typical malfunctions that may arise on this type of system. Finally, we will go through some troubleshooting steps to locate these malfunctions.

600. State specific operating characteristics of the hydraulic power system components.

Hydraulic Power System Components. The hydraulic power supply system discussed here provides hydraulic power to operate the aileron, rudder, and elevator booster cylinders. The hydraulic booster assemblies are not considered as part of the hydraulic power supply system and will not be discussed in this chapter. Now refer to foldout 1 in the supplement to this volume.

We will start this discussion with the reservoir and proceed through the rest of the system. The reservoir has a capacity of 2.0 gallons of hydraulic fluid. A sight level gage mounted on the reservoir gives a visual indication of the reservoir fluid quantity. A filler neck with a removable cap is provided for servicing the reservoir with fluid. An air vent filter is located at the top of the reservoir to filter the air entering the reservoir. A drain valve at the bottom of the reservoir provides manual overboard draining of the reservoir fluid. A flexible hose connects the reservoir to the suction boost pump because of the severe vibration of the pump. The suction boost pump is a centrifugal-type pump driven by a 3-phase, 400-cycle, AC induction motor. The suction boost pump has a shaft seal drain that empties into a drip pan. The drip pan has a manual drain valve to dump the fluid in the drip pan overboard. The suction boost pump produces a large volume of fluid at a low pressure; as an example, 20 gpm at 90 psi, which is more than enough to insure a positive supply of fluid to the engine-driven pumps. From the suction boost pump, you will notice a line that tees off and goes to a 2-way restrictor and check valve. This is the suction boost bypass line. It continuously circulates fluid from the suction boost pump back to the reservoir to provide a cooler operating boost pump. Just below the bypass line is a line going to the low-pressure warning switch. When suction boost pump discharge pressure drops below the low limit, the switch is actuated, causing an amber warning light on the hydraulic control panel to illuminate. Notice the ground on the warning light. This is the push-to-test-light circuit. When the indicator light is pushed, it completes a circuit to the ground that will automatically turn the light on (if the light is good). Figure 1-1 shows the hydraulic control panel which consists of gages, switches, and warning lights.

Now let's return to the hydraulic system. The ground test connection below the bypass line is furnished to allow a hydraulic test stand to be attached to the aircraft for ground testing. The check valve just below the ground test connection prevents draining the suction lines to the pumps when the suction boost pump is shut down. After passing through the check valve, the suction boost pump pressure flows to two identical hydraulic systems. For simplification we'll consider only the components in the No. 3 system. The fire wall shutoff valve shuts off hydraulic supply to the pump in case of fire emergency. The valve is motor operated with two positions: OPEN and CLOSED. With the valves open, fluid can flow to the engine-driven variable volume pumps. The pump has four lines attached to it: Pressure, suction, case drain and shaft seal drain. When the pump shaft seal leaks, the fluid is routed overboard. The case drain line routes internal pump leakage through the 20 psi relief valve back to the reservoir. When the engine pump is running, fluid under pressure (3000 psi) leaves the pressure port of the pump and flows through a filter assembly. This filter assembly is the NO by-pass type, but when clogged will cause the indicator button to protrude. Fluid now flows through a solenoid operated shutoff valve. This valve is spring loaded to the OPEN position and energized closed by the same switch used to close the fire wall shutoff valve. When both the fire wall and solenoid shutoff valves are closed, notice that fluid cannot flow from the suction boost pump, nor can it flow

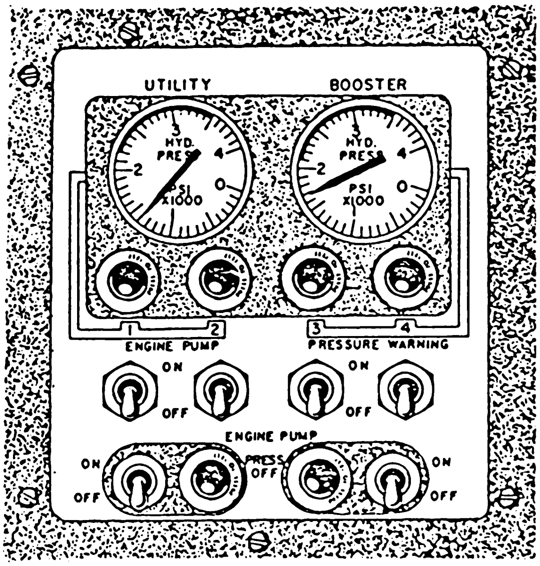

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Figure 1-1. Hydraulic control panel.

into the pressure system. Since the pump is always engaged by the engine accessory drive section, the fluid would become extremely warm after a prolonged period of time. To remedy this, there is a check valve between the suction and return line just above the No. 3 engine pump. The fluid that normally leaves the case drain line can now flow back to the suction side of the pump. The reason for this is that the spring in the check valve offers less resistance than the 20 psi relief valve. So, rather than the fluid from the case drain line returning to the reservoir, it flows back through the check valve and into the suction side of the pump. This is called a run-around circuit that cools the fluid and keeps the engine-driven pump lubricated.

A low-pressure warning switch is installed in the pressure line of each engine-driven pump. When pump discharge pressure drops below the low limit, the switch actuates and causes a warning light on the hydraulic control panel to glow. Downstream from the pressure switch is another check valve. This valve has three jobs. First, it prevents fluid of one hydraulic system pump from entering the other hydraulic system pump. As an example, if the No. 3 system was off but the No. 4 system pump pressure was reading 3000 psi, the fluid from No. 4 system could not flow to the No. 3 system pump. Without this check valve installed where it is, fluid from one system could motorize (cause the engine-driven pump to turn) the pump. Secondly, without the check valve, you could not determine which system was inoperative because the pressure switch would be actuated even though only one system was operating. Third, the first component downstream from the check valve is the ground test connection for the pressure hose of the hydraulic test stand. Notice that pressure from the ground test connection cannot flow to the pumps because of the check valves. Once the fluid passes the pressure line check valve, the fluid flows to the accumulator, relief valve, and pressure transmitter. The relief valve is set at 3450 psi. Any pressure in excess of this amount would be routed back to the reservoir through the return line filter. The accumulator has a 50-cubic-inch capacity with a 1500 psi precharge. A snubber is installed in the pressure line to the transmitter. The electrical power for the pressure transmitter comes from the booster hydraulic pressure circuit breaker.

Hydraulic Power System Operation. Prior to starting the engines, the suction boost pump switch should be placed to the ON position. This is the top switch on the copilot's instrument panel, as shown in foldout 1. This allows electrical power to flow from the hydraulic boost suction pump control circuit breaker to the suction pumps relay solenoid and then to ground. When this happens, all three contacts are pulled down. Then power is available to the suction boost pump motor, which in turn operates the centrifugal suction boost pump. Fluid is drawn from the reservoir and sent into the suction pressure line. The warning light should be on until the boost pump pressure builds up sufficient pressure to open the contacts of the pressure switch. With the boost pump pressure built up, the engines can be started.

To open the fire wall shutoff and solenoid-operated shutoff valves, the engine pump switches must be placed to the ON position. This completes an electrical circuit from the copilot's circuit breaker panel, through the engine pump switches, ice detector relay contact to the open side of the motor-operated fire wall shutoff valve. The solenoid-operated shutoff valve is spring loaded to the OPEN position, so simply dropping the electrical power will position it to OPEN. With the fire wall shutoff valve open, fluid from the suction boost pump can flow to the engine-driven pump. The pump produces a fluid flow through the pressure in-line filter and the solenoid-operated shutoff valve to the pressure switch. If the pressure is high enough, the pressure will force the contacts in the pressure switch to break the ground for the warning light, and the light will go out. Fluid then flows out through the check valve in the pressure line to the pressure transmitter, accumulator, and relief valve. Notice that just about everything is duplicated in the two systems except for the three components just mentioned above. These components are used for both systems. If either one of the hydraulic systems is operating (System No. 3 or No. 4), fluid would be available to the pressure transmitter, relief valve, and accumulator. There are two ways of electrically closing the suction shutoff and solenoid-operated shutoff valves. One is by pulling the fire control handles, and the other is to place the engine pump switches to OFF.

Let's discuss the fire control handles first. When the fire control handles are pulled, they complete a circuit to the solenoid in the ice detector panel (as shown on FO 1). The solenoid pulls the contact in the relay down, completing the circuit to the fire wall shutoff valve motor and the solenoid-operated shutoff valve. As you can see, even though the pump switch is ON, power flows through the contact in the ice detector panel and tees off to the fire wall shutoff valve and to the solenoid-operated shutoff valve and closes both valves. When this happens, the pressure warning light for that system will come on when system pressure drops off. To again open the valves, simply push

the fire handles back in. This method of shutting off the pressure is not recommended because, besides shutting off the hydraulic suction and pressure, it also shuts off the fuel to the engine. Of course with the fuel shut off, the engine will stop. The recommended method of checking the pressures in the system is simply by placing the appropriate engine pump switch to the OFF position. Notice that each pump switch has two contacts. With the switch in the OFF position, the indicator light automatically finds a ground through the lower contact of the switch. The other contact completes a circuit that allows electrical power to flow from the circuit breaker to the close side of the suction shutoff valve and solenoid-operated shutoff valve. To open the valves again, simply place the switch to the ON position. This will open the suction shutoff and deenergize the solenoid of the solenoid-operated shutoff valve.

Exercises (600):

Using foldout 1, answer the following questions:

1. What is installed in the vent line of the reservoir to prevent contamination from entering the reservoir?

2. Why is a hose used to connect the reservoir to the suction boost pump?

3. Hydraulic supply lines to the engine-driven hydraulic pumps are pressurized by what component?

4. Why does the suction boost pump have a bypass line?

5. When the amber low-pressure warning light comes on, what does this indicate?

6. Visually, how can you detect a clogged in-line pressure filter?

7. What unit prevents system pressure from actuating the low-pressure warning switch of a failed engine-driven hydraulic pump?

8. If a fire occurs, what provisions does the hydraulic system have to cut off the supply of fluid to the pumps?

9. Explain why a run-around circuit is used when the hydraulic pump shutoff valve is closed.

10. Name the two ways of shutting off fluid flow into the engine-driven pumps.

601. Describe hydraulic power system components in terms of purpose, function, quality, or operational characteristics.

Hydraulic System Components and Operation. In the simplest hydraulic systems, fluid stored in a reservoir is pumped, under pressure, by an engine-driven pump to an actuator, then returned to the reservoir. For smoothness of operation, components such as accumulators, pressure surge suppressors, and snubbers are added. Control devices like check valves and control valves are added for ON/OFF operation. For information and safety, indicators, fuses, relief valves, warning systems, and radiators are used. For this discussion, refer to foldout 2.

As stated earlier, this particular power supply system has many features that were not on the previous schematic we just discussed. Here again, we start our discussion with the hydraulic reservoir and proceed from there. This reservoir is an airless type designed to be pressurized by hydraulic system pressure. The reservoir has a manual air bleed valve used to bleed any air from the reservoir. An overboard drain is provided to route fluid overboard when the reservoir is mistakenly overserviced with fluid. Notice also that it has two return lines, one of which has a drain fitting. The pressure line is attached to the reservoir in order to force the piston (shown as the shaded area) in the reservoir to the right. As the piston moves to the right, it pressurizes the fluid. This fluid, under pressure, leaves the bottom line of the reservoir and flows toward the engine-driven pump. On its way, notice that the fluid must pass a quick disconnect with a cap. This is where the suction (return) hose of the hydraulic test stand would be connected. Just past the ground test connection, notice that the fluid divides and flows to two engine-driven pumps.

Since these two systems are identical, let's trace the fluid through the bottom hydraulic system only. This will simplify our discussion. Now, as the fluid tees off, notice that it flows through the suction quick disconnect of the pump. The pump is a variable volume pump capable of producing 26 GPM flow at full flow condition and is set to maintain system pressure of 3000 psi. The pump has hoses (not shown) that are located between the pump fluid ports and the quick disconnects. If metal tubing were placed in these locations, the metal tubing would be damaged because of pump vibration and engine movement.

Now trace the fluid flow from the case drain line back to the reservoir. Notice that it passes through a quick disconnect at the right side of the pump to the case drain filter assembly. This particular filter assembly is the *no bypass* type, but it has a contamination indicator button that

protrudes when the differential pressure rises too high. Next, it flows through a check valve and down to the hydraulic fuel radiator. The radiator is nothing other than a cooling coil that has fuel running through it. Even though both the fuel and hydraulic fluid flow through the radiator, they are separated by thin tubing. This allows the fuel to pick up any heat from the hydraulic fluid, thus cooling the fluid as it returns to the reservoir. Notice that the only fluid that flows through the radiator is the fluid from the case drain lines of the engine-driven pump. As each piston in this pump reaches its full stroke (approximately 562 times per second) it provides a natural "ripple" (pulse). This is a normal characteristic of piston-type pumps. If this pulse is not reduced, it could cause a destructive type of vibration being set up in the main part of the hydraulic system. To eliminate this problem, a surge suppressor is installed in the pressure line from the pump. The surge suppressor does not contain any air as does an accumulator to counteract the pressure surges. It is simply a round metal globe that causes the fluid to change its natural direction of flow by bouncing, splashing, and agitating the fluid from the pump. This action produces an acceptable pump pulse. From the surge suppressor, fluid flows through the pressure quick disconnect. Notice that quick disconnects are installed on all the lines on the pump. This will make the changing of the pump easier.

The next component in the pressure line is the low-pressure warning switch. Whenever the system pressure is low, the switch will complete a circuit from the *warning light* circuit breaker panel to the *check hydraulic gage warning light*. When the pressure is high enough, it will break the contact and turn the light out. Fluid from the pressure lines next goes through a check valve and filter assembly that has a bypass and contamination indicator button. The accumulator is a piston type with a precharge of 1000 psi. Fluid flows from the accumulator and goes out to the subsystems but also tees off and goes into the system manifold. The manifold has several components built into and attached to it. Notice that the system pressure runs into two check valves, one of which prevents fluid flow through it while the other allows the pressure to flow through it to the filter assembly. Notice also the pressure quick disconnect at the bottom left of the manifold. This allows the connection of the hydraulic test stand pressure hose. Whenever the test hose is not connected to the aircraft, the quick disconnect dust cap must be installed to prevent contamination of the system. From the filter assembly, fluid flows to the main system relief valve. If the pressure builds up in excess of system operating pressure, the relief valve will open and route the excess pressure back to return. As the pressure leaves the manifold, notice that it can flow out into the subsystem again. Also, it flows to a hydraulic fuse through a snubber to the pressure transmitter. The pressure transmitter sends an electrical signal to the cockpit pressure indicator. Now look at the lower right side of the system manifold. Notice a quick disconnect with a dust cap attached. This particular quick disconnect is used to service the reservoir with fluid, using a portable hydraulic servicing cart. The cart, when attached, sends fluid through the quick disconnect and filter assembly. The filter assembly insures that the fluid used for servicing the reservoir is clean. As the fluid fills the reservoir with fluid, it forces the piston (shaded area) to the left. Attached to the piston are some markings that indicate the amount of fluid in the reservoir. When the piston moves to the left far enough to the correct indicator mark, then the hydraulic servicing cart can be disconnected. Remember to put the dust cap back on the quick disconnect after the hydraulic servicing cart is removed.

Exercises (601):

Use foldout 2 in order to answer the following questions.

1. Explain how the reservoir is pressurized.

2. Why are quick disconnects attached to the pumps?

3. State the reason for having hoses instead of metal tubing on the pumps.

4. Describe the purpose of the surge suppressor.

5. What will cause the CHK HDY Cages warning light to illuminate?

6. As stated in the text, from which unit does the flow of hydraulic fluid come from before entering the hydraulic/fuel radiator?

7. Explain how the heat from the hydraulic system is transferred to the fuel in the radiator.

8. When the hydraulic reservoir is serviced using the portable hydraulic servicing cart, where would the cart be attached?

9. List at least four different components in or attached to the system manifold.

10. If the transmitter was to burst, what is installed in the system to prevent draining the complete hydraulic system?

602. Given hypothetical situations, solve hydraulic pressure supply system problems by stating the applicable procedure or specific trouble.

Troubleshooting Hydraulic Power Systems. When troubleshooting the hydraulic power supply, follow the applicable technical order (TO). In addition, be sure that you observe all safety precautions. We have chosen the hydraulic power supply system in foldout 1 as our representative system. Malfunctions in this system may occur in the electrical, mechanical, or hydraulic part of the system. Before you start troubleshooting, inspect the appropriate circuit breakers, fuses, and electrical and hydraulic connections. Also, check system components for security, evidence of leakage, and obvious damage.

The most common problems you will encounter on this type of system are these:

(1) Suction boost pump low pressure warning light comes on.

(2) Pressure transmitter indicates low or no pressure.

(3) Engine pump low pressure warning light comes on with engine running.

(4) Engine pump low pressure warning light will not come on when engines are shut down.

When the suction boost pump switch is placed to the on position but the light doesn't go out, there are several things you should check. First, if the suction boost pump is not turning, you should check for power at the cannon plug of the hydraulic boost pump. If no power is available, the wiring, boost pump switch, or boost pump relay is bad. If power is available at the boost pump, the boost pump motor is probably bad. If the boost pump is turning (noticed by a loud squealing noise) you should check the low pressure warning switch.

There are several things you should check if the pressure transmitter indicates low or no pressure. Since a pressure switch is installed in this circuit also, you should check it to see if it has turned the low pressure warning light on. Notice also that a direct reading gage is installed on the accumulator. Compare it with the transmitter reading. If these components indicate that the pressure is normal, you should start looking for the cause. You should check the pressure transmitter, electrical wiring, and the indicator in the cockpit. Also if the snubber is clogged it could cause low or no pressure.

When the engine driven low pressure warning light comes on while the engines are running, you should check the items above. As an example check the transmitter or accumulator gage to insure that the pressure is low. If they indicate that the pressure is correct, you can suspect that the pressure switch is bad. If they indicate that the pressure is low, you can assume that the pressure switch is working properly, and that some other component has malfunctioned. One of the first components to suspect is the engine-driven pump. It will be necessary to take the pump off the aircraft in order to check it for proper flow and pressure settings. More about this later on in this chapter. Closing the fire wall shutoff or pressure shutoff valves would stop the flow of fluid through these valves, which would cause the low pressure switch to come on. Make sure that the engine pump switches or control handles are in the proper position. If the switches are in the proper position and the valves are still shut, you can suspect bad switches, relays, or valves themselves. Two other things that could cause low pressure in the system are the pump pressure filter and the relief valve. If the pressure filter were clogged or almost clogged, the flow of fluid into the system could be restricted. If the main system relief valve is set too low or has internal leakage, system pressure could be routed back to return.

At times the engine pump low pressure warning light may fail to come on while the engine is shut down. To check this situation, first notice that the low pressure warning lights have a push to test feature. If you push the light, the ground on the light will make contact. If the ground is made, the light should come on. If the light does not come on, you can suspect that the light bulb or electrical wiring to the light is bad. Another thing that could cause this type of malfunction is the low-pressure warning switch, or electrical wiring to the switch. To make sure that power is reaching the pressure switch, disconnect the cannon plug to the pressure switch and check to see if it is receiving electrical power. If power is available you can suspect that the pressure switch is defective. Also, this problem could happen if one of the pressure check valves is leaking internally. As an example, if both the No. 3 and No. 4 engines are running and you shut down No. 3, the low-pressure warning light should come on. By looking at foldout 1, you can see that if the pressure check valve is leaking internally, fluid from the No. 4 engine could enter the No. 3 engine system and keep the light out.

Exercises (602):

Use foldout 1 to answer the following questions:

1. With only No. 3 engine running, the booster system pressure indicator on the copilot's panel indicates low or no pressure. Also the No. 3 engine pump low-pressure warning light comes on. The No. 3 engine-driven pump switch is on, and the valves are open. What are some probable causes for this trouble?

2. The booster system pressure indicator on the copilot's panel indicates low or no pressure but the engine pump low-pressure warning light stays out. With No. 3 and No. 4 engine-driven pump switches on, you determined that sufficient hydraulic pressure is available for system operation. What is a possible cause for this trouble?

3. While the booster hydraulic system is operating, the suction boost pump low-pressure warning light goes on. You have checked all electrical leads to the boost pump motor and found the pump motor to be operative. What is a probable cause for the low-pressure warning light coming on?

4. During a check of the booster hydraulic system, the engine pump low-pressure warning light on No. 3 engine does not come on when you push the press-to-test light. After you replace the bulb, the light still does not come on. What should you have checked first?

1-2. Pneumatic Power System

Each manufacturer of an aircraft determines what components, systems, style, type, etc., of aircraft to build. One manufacturer might want all hydraulic systems, while another may want all pneumatic systems. Still another may want a combination of each.

In the early types of aircraft, a pneumatic system consisted of an air flask (charged to a specified pressure) used to operate one or more systems in an emergency. As you will see in the following chapters in this volume, pneumatic systems can be, and in many cases are, much more complicated than this. In this section we are going to talk about the pneumatic power system components and system operation.

603. Specify constructional/operational features of various pneumatic components in the pneumatic power system.

Pneumatic Power Supply System. In this discussion we have selected a pneumatic system that has just about everything you would normally find in a pneumatic system. Refer to figure 1-2. This system is a high pressure (3000 psi), self-sustained pneumatic system that supplies compressed air to the various pneumatic subsystems. Figure 1-2 only shows the pneumatic power supply system. Later on in this volume we will show how these subsystems operate when we talk about the landing gear and flaps. But for now though, we concentrate only on the pneumatic power supply system.

Pneumatic system components. The air compressor maintains the aircraft pneumatic system's pressurization during flight. The air compressor is driven by a hydraulic motor powered by the utility hydraulic system. Compressor operation is controlled by the pneumatic system's manifold pressure sensing switch. The compressor cuts in when system pressure drops to 2750 psi minimum, and cuts out when system pressure reaches 3050 to 3200 psi.

The moisture separator is capable of removing up to 95 percent of the moisture from the air compressor discharge line. The automatically operated condensation dump valve purges the separator oil-moisture chamber by means of a blast of air (3000 psi) each time the air compressor shuts down. The condensation dump valve solenoid is energized and deenergized by a pressure switch. When energized, it prevents the air compressor from pumping air overboard; when deenergized, it completely purges the separator reservoir and lines up to the air compressor. A filter protects the dump valve port from becoming clogged and thus insures proper sealing of the passage between the reservoir and dump port. An internal check valve protects the system against pressure loss during the dumping cycle and prevents back flow through the separator to the air compressor during the relief condition. The relief valve opens when system pressure reaches 3500 psi and reseats at 3250 psi to protect the system against overpressurization and thermal expansion.

The chemical air drier used in the high pressure pneumatic system further reduces the moisture content of air emerging from the moisture separator. It also serves to reduce the amount of air compressor lubricating oil and foreign material entering the subsystems.

An air servicing (schrader) valve is installed in the pneumatic system for the purpose of servicing the system while the aircraft is on the ground. The air filter in the ground charge line prevents the entry of impurities into the system from the ground servicing source. The air pressure gage, adjacent to the ground servicing valve, indicates the pressure of the system.

The hydraulic system consists of a solenoid-operated selector valve, flow regulator, hydraulic motor, and motor bypass (case drain) line check valve. When the selector valve is energized, it allows hydraulic fluid under pressure to run the hydraulic motor. Deenergized, the selector valve blocks off hydraulic pressure, which stops the motor. The flow regulator meters the flow of fluid to the hydraulic motor, preventing excessive speed variation and/or overspeeding of the compressor. A check valve in the motor bypass line prevents system return line pressure from entering the motor, thus preventing motor stall.

Pneumatic system operation. Notice in figure 1-2 that the air compressor is mounted to the access door. When the door is down (as shown) the lubricating pump inside the compressor would not lubricate all the moving parts properly. To prevent operating the compressor while the door is down, two switches are used to break the electrical circuit in the pneumatic system. Let's assume that the access doors are closed and the switches are actuated closed to complete the electrical circuit. Notice that the electrical power flows from the 28 VDC bus circuit breaker through the door access switches and down to the pressure sensing switch and heating blanket thermostat. If the temperature is low, the thermostat allows the electrical power to proceed on to the heating blanket. The heating blanket prevents the moisture inside the moisture separator from freezing. If the pressure sensing switch is closed, notice that power can energize the moisture separator dump valve and the solenoid-operated hydraulic selector valve. When the solenoid-operated selector valve is energized, it directs hydraulic fluid under pressure through the flow regulator to the hydraulic motor attached to the air compressor. As the motor turns, it causes the compressor to build up pneumatic pressure. Notice the seal drain on the access door. Any leakage of the shaft seal of the hydraulic motor will come out this area.

The equipment auxiliary air system supplies the air compressor with air when the engines are operating. This insures an adequate supply of air to the compressor at all altitudes. The auxiliary air is first filtered through a high-temperature 10-micron filter that has a built-in relief (bypass) valve. After it flows through the filter, it enters a

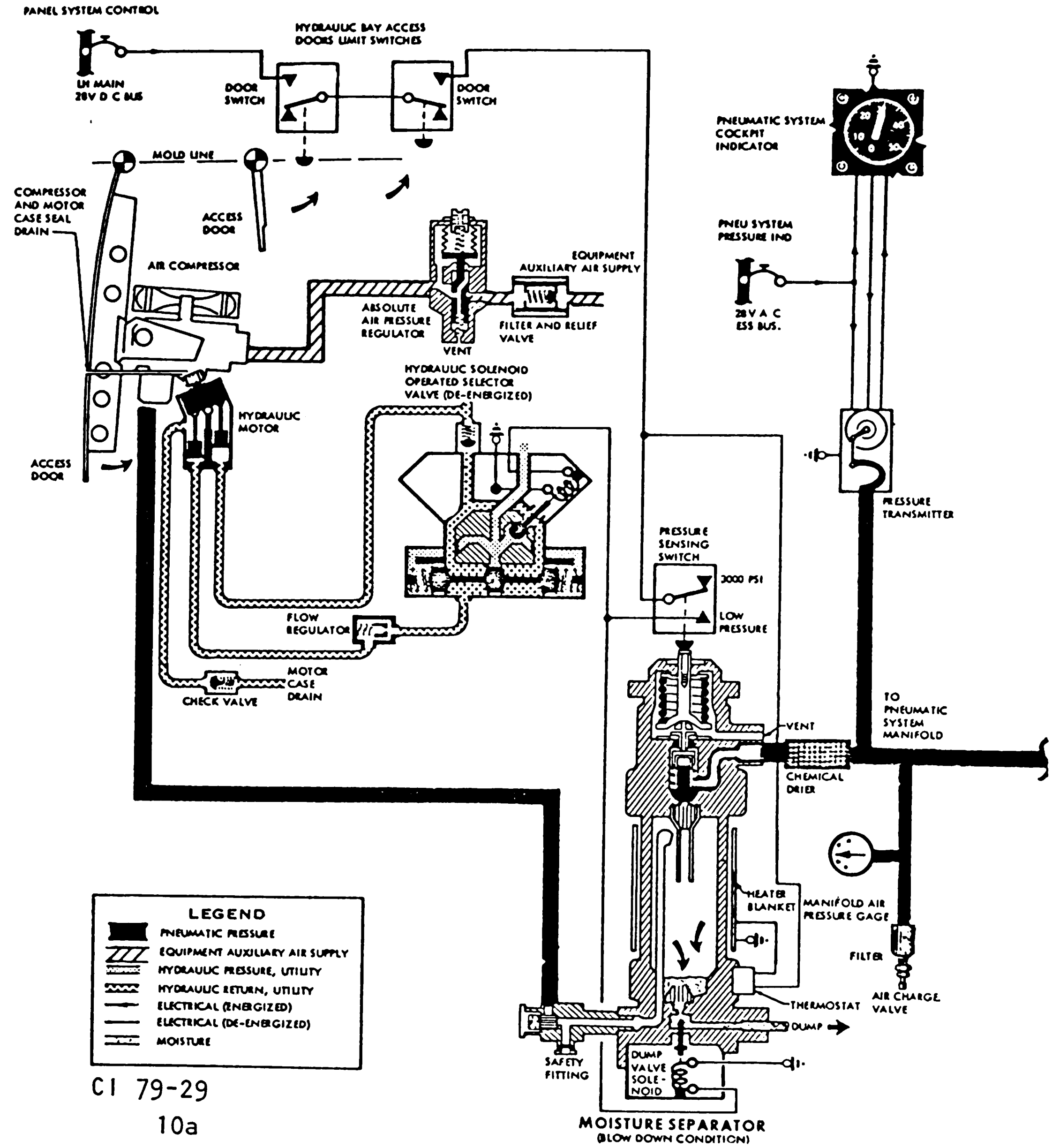

Figure 1–2. Pneumatic power supply.

pressure regulator. The air pressure regulator provides a stabilized source of air to the inlet port of the air compressor. The air compressor being run by the hydraulic motor compresses the inlet air and sends it out the pneumatic pressure line to the moisture separator. Since the solenoid on the bottom of the moisture separator is energized closed, the pneumatic pressure will flow up through the check valve and out to the exit port. The pressure will next flow through a chemical drier and out into the pneumatic system manifold. Notice also that the pressure can flow to the pneumatic system pressure transmitter, which sends an electrical signal to the pressure indicator in the cockpit.

When pressure builds up to the specified amount in the system, the pressure switch on top of the moisture separator opens. When this happens, the solenoid on the hydraulic selector valve deenergizes, and the air compressor hydraulic motor stops running. At the same time, the solenoid on the bottom of the moisture separator is also deenergized. The dump valve automatically springs open. When this happens, any moisture in the moisture separator is dumped overboard. The system will remain in this position until the pressure decreases enough to cause the pressure switch to be activated again.

Exercises (603):

1. Explain why the air compressor should not be operated while the access door is hanging down.

2. What provides a stable pressure head to the air compressor inlet port?

3. If the shaft seal is leaking on the hydraulic motor, how would this be indicated?

4. If the temperature is below freezing, what prevents the moisture in the moisture separator from freezing?

5. What components are provided for external servicing of the pneumatic system?

6. What protects the dump valve port of the moisture separator assembly from becoming clogged?

7. If the air compressor was overspeeding, what could possibly have caused this malfunction?

8. What two components are energized when the moisture separator pressure switch is closed?

1-3. Pneudraulic Power Supply Maintenance

Because of the numerous components found in the hydraulic/pneumatic power supply system, it would be impossible to talk about the maintenance performed on each and every component. We have selected specific items that we feel are common to just about every hydraulic power supply system. In this section we go over general procedures used to inspect, service, perform operational checks, and remove and replace components.

604. Specify hydraulic power system item inspection requirements and the procedures to follow in servicing specific items.

Inspection. When inspecting the pneudraulic power system, one of the first things you should look at is the reservoir. Is it serviced properly? Is it low? An aircraft that repeatedly returns from a mission with a low reservoir could indicate that there is a leak in the system. Check the air charge in the accumulator. Check all the components for leakage, mounting, and safety wiring. Check tubing and hoses for damage. If filters are installed in the power system, check to see if the filter buttons are popped, which would indicate clogged filters. More detailed inspection procedures can be found in the applicable aircraft –6 technical order.

Servicing. The servicing section of the applicable –2 TO contains instructions for servicing the various systems and components of the aircraft. In addition to the TO information, symbol markings are used to identify servicing points, ground handling locations, and hazardous areas. Figure 1-3 illustrates the servicing and ground-handling markings. Notice, for instance, that these markings show where you would place a jack for jacking an aircraft or attach a servicing cart to service a reservoir. Depending on the background color, servicing markings are either black or white. The ground-handling markings are an orange-yellow color with a black or white outline. Here we cover general procedures that can be used to service accumulators and reservoirs.

Accumulators. In order to better understand how to service an accumulator with air, refer to figure 1-4.

Notice the nitrogen servicing cart, which can be used in place of an air compressor to service an accumulator with air. Notice also in the insert, how the air servicing air chuck (7) is used to connect the air servicing hose to the air servicing valve (6).

When you find that an accumulator needs servicing (charging with dry air or nitrogen), begin by depressurizing the hydraulic system. This is to make sure that you get an accurate measurement of the air charge. Some other names of the air charge that are put in the accumulator are "initial air charge" and "preload." Next, remove the air servicing

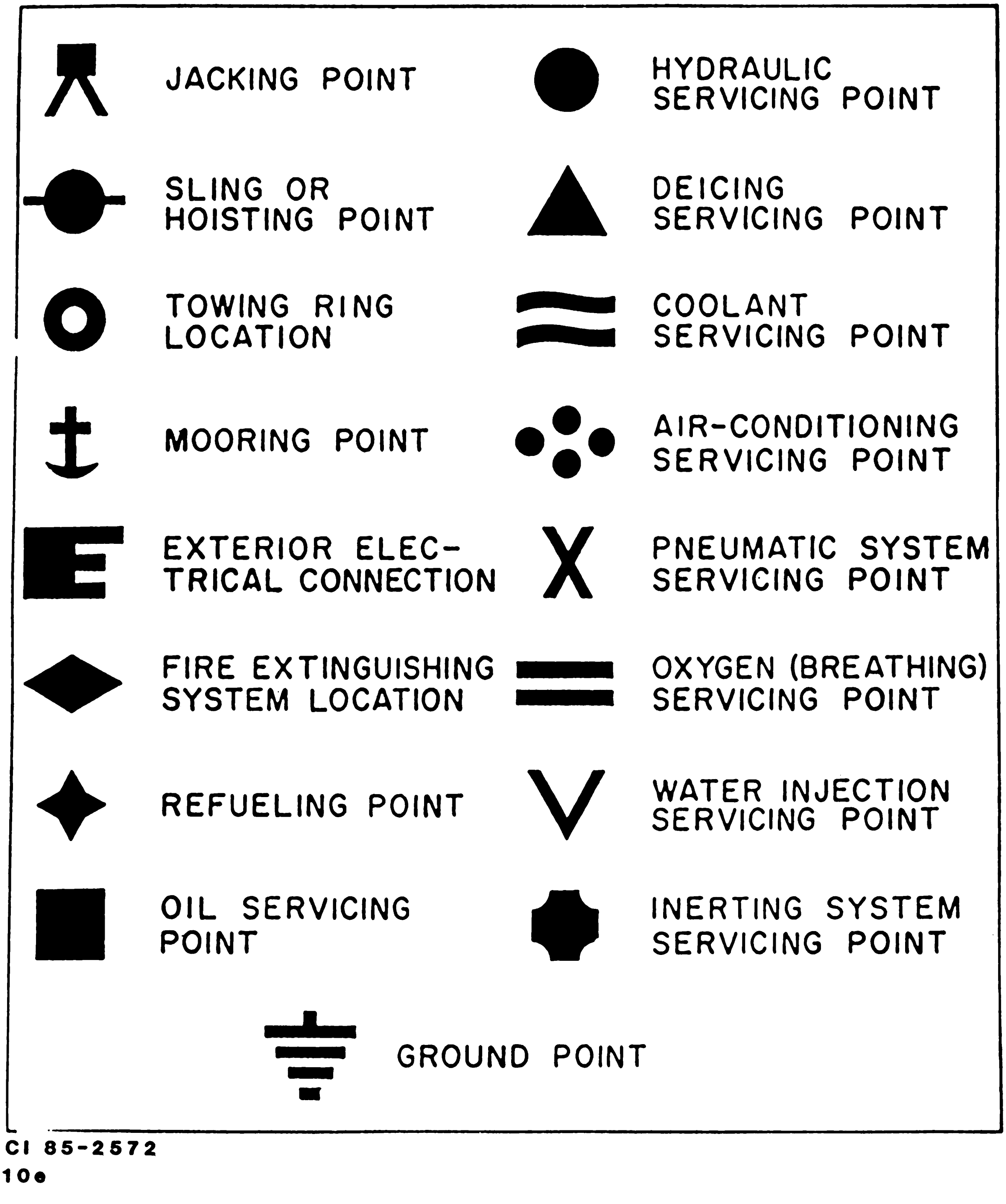

Figure 1–3. Ground-handling and servicing markings.

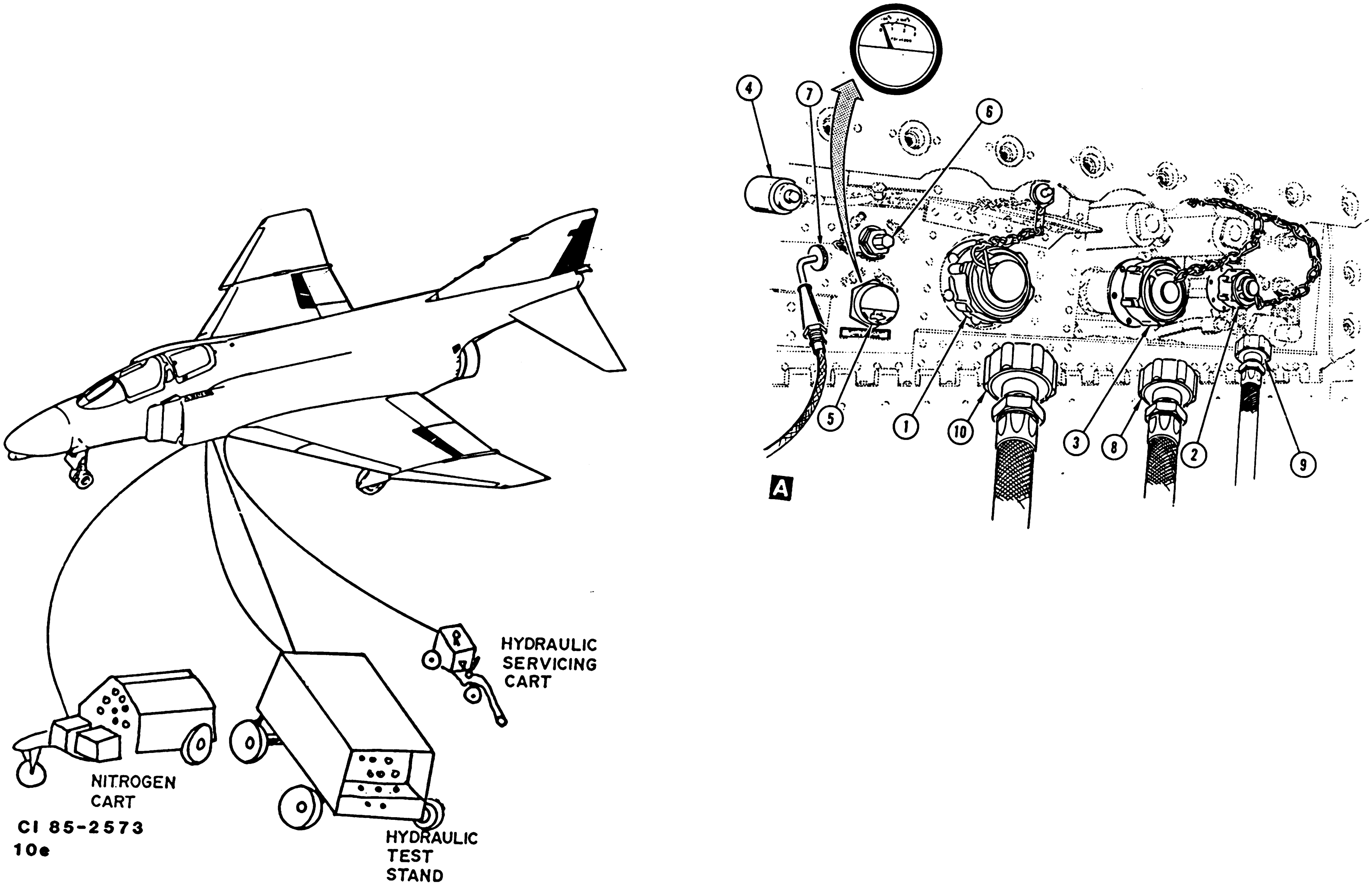

Figure 1–4. Pneudraulic servicing points.

valve cap and connect the external pneumatic power source to the accumulator air charge valve. Loosen the air charge valve swivel nut (MS28889 schrader valve). Charge accumulator to specified air charge given in the applicable TO. An important point to remember is that the amount of air pressure placed in the accumulator depends upon the ambient temperature. If you will recall, temperature will affect a gas by expanding it as the temperature rises and contracting it as the temperature falls. When the gas in an accumulator expands, the pressure increases; and as the gas contracts, the pressure decreases. For example, assume that an accumulator requires an initial air charge of 1000 psi at 70°F. On this particular day, the sun is very hot and the ambient temperature is 100°F. If you put 1000 psi in the accumulator disregarding the temperature, the gas will contract as it cools and, as it does, the pressure will decrease. Let's go a little farther and say that it cools down to 70°F. Instead of the accumulator having 1000 psi at 70°F, it might have only 920 psi, a pressure decrease of 80 psi. This could cause the accumulator to bottom each time an excessive amount of hydraulic pressure is applied to the accumulator. Notice the air servicing gage (5) on figure 1-4 that indicates the amount of air pressure in the accumulator. After charging the accumulator, tighten the swivel nut on the servicing valve, disconnect the air chuck, check for leaks, and install valve cap. It should be noted that each accumulator will have different preloads, but the servicing procedures just discussed are basically the same for any hydraulic accumulator.

Reservoirs. To insure that the reservoir is serviced properly, use the aircraft TO or follow the instructions on the data plate. The data plate is usually located close to the reservoir being serviced. These instructions tell you the type of fluid that should be used, the position of the system, and the system pressure that must exist before you start to service the reservoir. For example, if system pressure is 3000 psi instead of zero psi, the reservoir may seem low because some of the fluid is now stored in the accumulator. Also if you check the fluid level with the subsystems in the wrong position, the reservoir may indicate too much or not enough fluid. The reason for this is that some actuating cylinders displace more fluid when they are retracted than when they are extended.

The method used to service a hydraulic reservoir is primarily determined by the reservoir type and location. Some are serviced by removing a cap or plug from the filler port and pouring fluid directly into the reservoir. Another type of reservoir is serviced with a pressure servicing cart or a hydraulic test stand. Refer to figure 1-4 as we cover how to service a reservoir using a servicing cart. First, relieve the system pressure by operating one of the aircraft's subsystems, (brakes, flight controls). With the pressure depleted, check the air charge in the system accumulator. Service the accumulator if necessary before servicing the reservoir. The hose (9) from the hydraulic servicing cart, shown in figure 1-4, is attached to the quick disconnect (2) as shown in the insert of figure 1-4. With the servicing cart connected to the aircraft, pump the fluid into the reservoir. Do not pump the fluid into the reservoir too fast, because this could rupture the reservoir. Notice the air bleed valve (4) that is used to release any trapped air in the reservoir. This valve should be depressed while pumping fluid into the reservoir until a steady stream of clear hydraulic fluid flows from the air bleed valve drain line (not shown). You would then continue pumping fluid into the reservoir until the reservoir is serviced with the specified amount. Now notice the hydraulic test stand in figure 1-4. It too can be used to service a reservoir with fluid. In the insert, the hydraulic test stand hoses (8) and (10) can be attached to quick disconnects (1) and (3). Using the test stand's fill system, pump fluid through the test stand hoses to fill the reservoir.

Exercises (604):

1. Besides the TO, what else can be used to indicate servicing points on an aircraft?

2. What is the first step that should be done when an accumulator needs to be serviced with air?

3. What should an accumulator be inspected for?

4. Generally speaking, if an accumulator is normally serviced with 1000 psi of air at 70°F, should the pressure be increased or decreased if the ambient air is 30°F?

5. Name the two items that can be used that give instructions on servicing a reservoir.

6. List three things that are usually found on a data plate for servicing a reservoir?

7. When using a servicing cart to service a reservoir, what could possibly happen if you pump the fluid into the reservoir too fast?

8. List some items that could cause the reservoir to indicate that the reservoir is low.

9. How could you tell if a filter was clogged during an inspection?

10. What general requirements can all components be inspected for?

605. Identify the source of hydraulic/pneumatic power for an operational check from given situations, and specify general operating principles about a hydraulic power supply system.

Operational Checks. You can perform an operational check of the hydraulic power system by either connecting a hydraulic test stand to the aircraft or running the aircraft engines. Figure 1-4 shows how a hydraulic test stand would be connected to an aircraft. If a hydraulic test stand is used, it can usually check everything in the system except for the hydraulic pumps themselves. In order to check the pumps, either the engines will have to be run or the pumps removed from the aircraft and bench checked in the shop. When an operational check is required on a pneumatic system, an air compressor is usually connected to the aircraft in order to pressurize the system. Here again, depending on the system, the air compressor should be able to pressurize the complete system.

As we said, the other way of performing an operational check of the hydraulic power system is to run the engines. With the aircraft engines running, you can check everything in the system except for the relief valves. The reason for this is that the compensators in the pumps are set at a certain amount while the relief valve is set to relieve excessive pressure (above the pump compensator setting). With the engines running, you would never be able to reach the relief valve setting to check it for proper operation. To give you an idea on what you should look for or do when performing an operational check, the following list is provided.

Prior to operational check:

a. Get the appropriate technical order.

b. Gather all the test equipment tools required for the check.

c. Check the fluid level in the reservoir.

d. Check the air charge in the accumulators.

e. Many warning lights have push-to-test circuits. Test the lights to insure that none is burned out. Many man-hours have been spent troubleshooting a system when only the light bulb had burned out.

f. Check the position of the controls and circuit breakers.

During operation:

a. Check to see that the pressure rises smoothly during engine startup, and that the warning lights go out at specified pressure settings.

b. Verify the pressure readings in the cockpit with the pressure readings on the system accumulators. In some cases special test gages have to be installed during the operational check.

c. Listen for any unusual noises or sounds. As an example, a hissing noise may indicate bypassing of fluid in the system.

d. Look for any external leakage.

After the operational check has been done and the engines are shut down, remove any test equipment that was used.

Exercises (605):

1. Match the hydraulic/pneumatic power source in column B that must be used to perform an operational check of the situation in column A. Items in column B may be used more than once.

Column A	*Column B*
____ (1) Pilot reports that the hydraulic pump is leaking.	a. Run the aircraft engines
____ (2) The schrader valve on the pneumatic servicing connection is leaking.	b. Use portable hydraulic test stand.
____ (3) A relief valve was found leaking. It was removed and replaced.	c. Use portable air compressor.
____ (4) An accumulator shows signs of external leakage of hydraulic fluid.	

2. You are performing an operational check on an engine-drive pump that has just been replaced. Using this situation, come up with the most logical answers to the following problems.
   a. The pressure indicator in the cockpit is reading high. You suspect that the indicator is in error. What can you do to verify this?

   b. The pilot who is performing the engine run asks you what the plus or minus is on the pump pressure. You say that you don't remember. What have you done wrong?

   c. You hear a grinding noise coming from the pump just replaced. After investigation, you determine that the pump is cavitating because of the lack of fluid. What should you have done to prevent this from happening?

606. Specify removal and replacement features of specific units in the pneudraulic system.

Removing and Replacing Pneudraulic Components. It would be impossible for us to cover the removal and installation procedures for every component in the pneudraulic power system on every aircraft in the Air Force inventory. We will talk about procedures that are common on such units as the filter, engine drive pump assembly, and a chemical drier cartridge.

Removal and replacing of filter element. Filter elements are normally replaced periodically with a serviceable filter. This means that at certain intervals these elements are also

replaced when a system is contaminated, or suspected of being contaminated. The following procedures are typical for most aircraft filter elements. Refer to figure 1-5. Relieve system pressure by operating some subsystem (brakes, flight controls, etc.). If the system has a pressurized reservoir, be sure to depressurize it. Next, cut the lockwire and unscrew the filter case (bowl) from the filter head. Pour the fluid in the filter bowl out and check the interior of the case for contamination. Small particles of dirt indicate that the filter element is doing its job. An excessive amount of particles could indicate that the system is contaminated and in need of flushing. (Flushing will be covered later on in this chapter.) Next remove the filter elements to check them for damage. A filter element that is damaged (cut, torn) could mean that the filter element is allowing unfiltered fluid into the system.

Prior to installing a new filter element in the filter assembly, install all new O-ring seals. Install the filter element into the head of the filter assembly. Next, wipe the filter bowl clean and fill it with clean hydraulic fluid. (This helps to eliminate the injection of air into the system.) Screw the bowl into the filter head and torque in accordance with the maintenance instructions. Next, safety wire the filter bowl and wipe off any excess fluid. After filter elements are replaced, be sure to pressurize the hydraulic system and check the filter assembly for leaks.

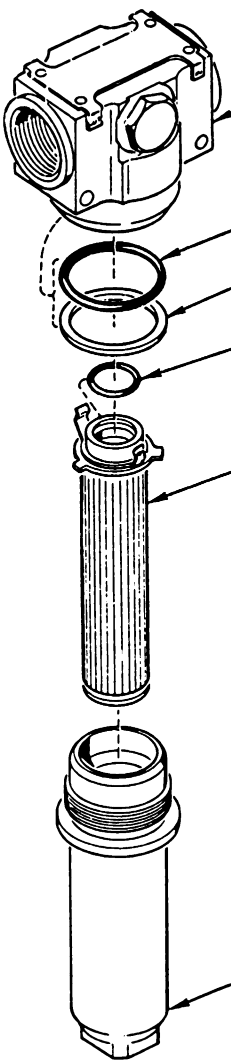

Figure 1-5. Typical filter element replacement.

Removing an engine-driven pump assembly. As with the removal of a filter assembly, the hydraulic system pressure should be depleted. Some aircraft have fire wall shutoff valves that should be closed to prevent draining the lines of fluid during pump removal. Next, disconnect the lines to the pump. There are normally four lines attached to a pump assembly: supply, pressure, case drain, and shaft seal drain. Some aircraft have large clamps that hold the pump in place, while others are held in place by nuts and washers. In any case remove the clamp or nuts and remove the pump from the mounting pad. If a new pump is going to be installed on the aircraft, the fittings must be removed from the old pump and installed in the new pump. Be sure to install the fittings properly. Before the new pump is installed, it should be primed. If it is not primed, it could be damaged or send air into the system.

Priming a pump. When priming an engine-driven pump, the air space in the pump is replaced with fluid. This can easily be done by attaching a supply of fluid to the inlet or supply port and rotating the pump shaft until a clear supply of fluid comes out of the pressure port. When the pump is completely full of fluid, there is no way that it can send any air into the system after it is installed.

Installing a pump. After the fittings have been installed and the pump primed, the spline of the pump shaft should be lubricated. This not only makes the pump easier to install into the mount pad but it also keeps the spline from wearing. Many pumps require a seal between the pump mount pad and the pump itself. Be sure to check the TO for the installation of such a seal. Install the pump to the pump mount pad making sure that it is aligned properly. Then install the clamp or nuts that secure the pump to the mount pad. Next install the lines, and wipe off any excess fluid. Because the pump is mounted to the engine, the engine will have to be run to check the pump for leakage and proper pressure readings.

Removing and replacing a chemical drier cartridge. Preventive maintenance of this component consists of replacing the cartridge when it becomes saturated with moisture. As with the filter elements, change them periodically. To replace the cartridge in the chemical drier, use the following procedures. Bleed the air from the system. Remove the plug from the outlet end of the air drier housing and discard the O-ring seal. Next remove the old cartridge from the housing and discard the cartridge.

Clean the interior of housing with cloth saturated in cleaning solvent, then dry the housing with clean, lint-free cloth. Also check the housing for signs of corrosion. Remove the protective covers from the new cartridge. If the protective covers are not removed, air will not pass through the cartridge. Install the cartridge so that the arrow and the word ''flow'' are pointing in the direction of the outlet port.

Then reinstall the outlet end plug and use a new O-ring seal. Next, pressurize the system and check for leaks.

Exercises (606):

1. What are the four lines that are normally attached to a pump?

2. Why is it necessary to prime a pump?

3. Why are the splines on the drive shaft lubricated?

4. After an engine driven pump has been installed, explain why a hydraulic test stand cannot be used to check the pump out.

5. Outline the procedures to follow when replacing a filter element.

6. Why do you fill the bowl with fluid prior to installing it?

7. Where would you find the torque value on the filter bowl?

8. If the filter bowl was completely filled with dirt particles, what could this indicate?

9. What will happen if the protective covers are not removed from the chemical drier cartridge?

10. When installing the cartridge into the drier housing, you should point it in which direction?

607. Cite the reason for draining, flushing, and purging; specify the reason for conducting specific procedures during flushing and draining.

Hydraulic systems should be drained and flushed whenever contaminants are present. The draining and flushing procedures vary somewhat for the different types of aircraft in the Air Force inventory. It is not our interest to cover all the procedures in this section. We will cover procedures that are common and also talk about the trouble that makes flushing and draining necessary.

Fluid Contamination. Whenever it is suspected that a hydraulic system has become contaminated or the system has been operated at temperatures in excess of the specified maximum, make a check of the fluid. Large particles of impurities in the hydraulic system are an indication that components in the system are wearing. Discoloration of the fluid is another indication that fluid is contaminated, either from being mixed with other fluids or from being overheated.

To determine if the hydraulic system is contaminated, take fluid samples from the reservoir and various other locations in the system. Take these samples in accordance with applicable aircraft manufacturer's instructions for that particular hydraulic system. Some hydraulic systems are equipped with permanently installed bleed valves for taking liquid samples, whereas on other systems, lines must be disconnected to provide a place to take a sample. There are various test procedures used to determine the contamination level in hydraulic fluids. If your shop is equipped with a fluid contamination kit, you can perform the test yourself. However, since special equipment is required for these checks, the hydraulic fluid will probably be sent to a laboratory where the contamination test is made.

Draining the Fluid from a Hydraulic System. If the fluid from a contaminated hydraulic system must be drained, you should start with the reservoir first. Most reservoirs have some type of drain that you can open to drain it. If not, a line at the bottom of the reservoir should be loosened just enough to allow the fluid to drain from the reservoir. At all dead-end points from which the fluid cannot be readily drained, open the tubing or hose assembly connections at the fittings to let the fluid drain out. Remove actuating-cylinder valves and other units if the fluid trapped in them cannot be drained by disconnecting a line.

Flushing. Flushing a hydraulic system can be as simple as hooking a hydraulic test stand up to the aircraft and operating the subsystems a sufficient number of times to remove all the contaminated fluid. In other instances, it can get quite involved. To show you how involved flushing a system can get, we cover the flushing procedure of a typical system. Refer to figure 1-6. Let's say that engine-driven pump (1) has failed. First, remove the failed pump and flexible hose assemblies (2) that attach directly to the pump. Next remove and replace the elements in the filter assembly (4). Some valves such as (5) will have to be removed and new ones installed. Other valves will be removed, cleaned, and reinstalled. As you can see in figure 1-6 many of the valves (6, 7, 10, 11, 13, and 14) have been bypassed with flexible hose, and other sections have been capped off. The reservoir (8) will have to be drained. Once all this work has been done, fluid is then forced through the lines to remove any contamination from the system. When the contamination has been removed, the system must be assembled into its original condition. Sound like a lot of

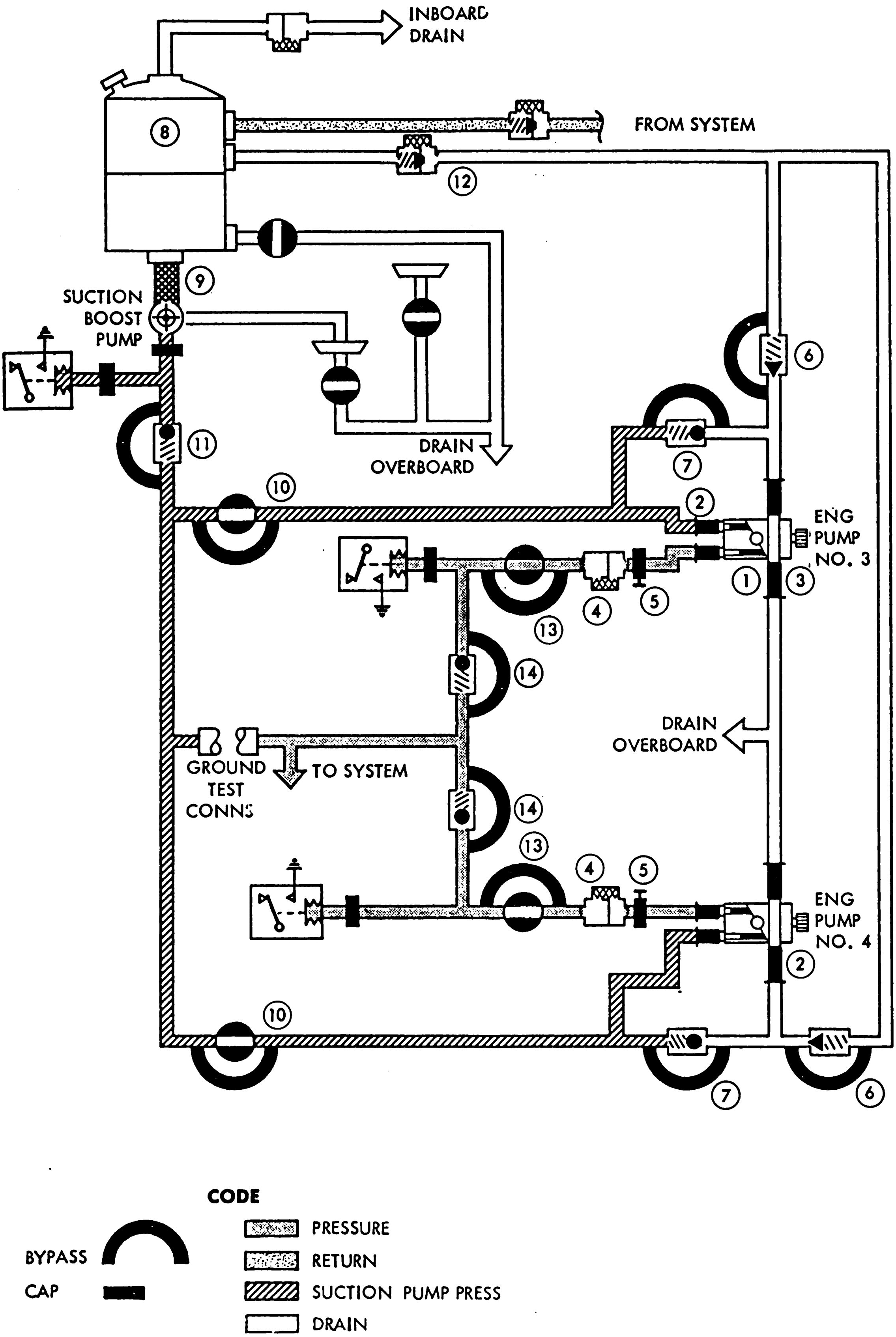

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Figure 1–6. Flushing procedures.

work? You bet. This is why we stress cleanliness of the fluid and the elimination of air in the system.

Purging. Purging is defined as the cleansing of a system. Purging is primarily associated with pneumatic system (gases) as opposed to flushing, which we associate with hydraulic systems (liquids). Even though these two words are used interchangeably, from now on in this course, we will associate flushing with hydraulic systems and purging with pneumatic systems. Purging of a pneumatic system is accomplished by attaching an air source (air compressor or nitrogen cart) to the system and sending air pressure through the system to remove any contamination or condensation from it.

Exercises (607):

1. How can you tell if a system is contaminated?

2. Why is it necessary to disconnect and even sometimes remove some units from an aircraft to properly drain a system?

3. Why is is necessary to bypass some valves when flushing a system?

4. Define purging.

5. What else besides contaminants can be purged from a pneumatic system?

1-4. Bench Check and Repair of Pneudraulic Power Systems Components

This section discusses the bench check and repair of specific components in the hydraulic power system. Two items which consistently malfunction and which you might have to bench check and repair are the hydraulic pump and the system accumulator. Since most pumps cannot be repaired because of –6 requirements, we will not go into the repair of the pump. We will, though, discuss the general procedures you would use when bench checking a pump for serviceability. Then we will discuss one of the most frequently malfunctioning items in the hydraulic power system, the system accumulator.

608. State the procedures to follow when bench checking an engine-driven hydraulic pump.

Pump Testing. Although many engine-driven hydraulic pumps are not repaired because of –6 restrictions, you will more than likely perform a bench check or test of the pump itself.

When you bench check a pump it should be installed in a test set-up similar to the one shown in figure 1-7. The procedures given here for bench checking an engine-driven pump will be of a general nature since all pumps will differ in some respect.

Notice in figure 1-7 that the pump is mounted to an electric motor (HCT–6 or equivalent), which has a torque motor attached. With the pump installed on the pump test pad of the test stand let's see how the lines are attached. This particular pump has four connections: pump suction, pump pressure, case drain, and shaft seal drain. Notice that the shaft seal drain is attached to a graduated beaker. This will measure the amount of shaft seal leakage. The pump is supplied with fluid from the reservoir through a 10 micron filter. In most cases the fluid used for testing the pump will be maintained at a specific temperature. On some test stands the reservoir is pressurized to supply fluid under pressure to the pump being tested. In other cases the fluid is pressurized by a boost pump which will supply the engine-driven pump being tested with the specified amount of fluid needed during testing. Now, trace the fluid flow from the pressure port of the pump. Notice that it must pass through a needle valve, flowmeter, and in some cases a heat exchanger (cooler), back to the reservoir. The case drain or by-pass line has a similar set up back to the reservoir. Some of the tests you perform on a pump are listed below. Note: Under no circumstances should the following procedures be used to bench check a hydraulic pump. For specific testing data refer to the technical order for the pump being tested.

- Pump break-in.
- Compensator (pressure) setting.
- Capacity (flow) test.
- Case drain (by-pass) test.
- Drive shaft torque test.
- Static pressure (shaft seal) test.

Pump break-in. Many engine-driven pumps must have a break-in period, especially if new parts have been installed. This break-in consists of running the pump at specified pressure and rpm settings for a specified length of time. As an example, run the pump at 1500 psi at 1800 rpm for 10 minutes; then increase the rpm to 3750 rpm, while still maintaining the pressure at 1500 psi. Do this until the maximum pressure and rpm have been reached. This operation will insure that the pump will function properly in all pressure and RPM settings.

Compensator (pressure) setting. With the pump attached to the pump test pad, as shown in figure 1-7, and running at the specified speed, close the pressure line needle valve. Observe the pressure reading on the pressure line pressure gage. If the pressure is incorrect you should adjust the pump compensator as shown in figure 1-8. After adjustment, alternately open and close the needle valve. This will cause sudden pressure surges, but the compensator response should be instantaneous and it should recover to adjusted limits.

Capacity (flow) test. In order to check for flow, all the shut off valves must be open. The pump will produce the specified amount of flow, which can be measured by the

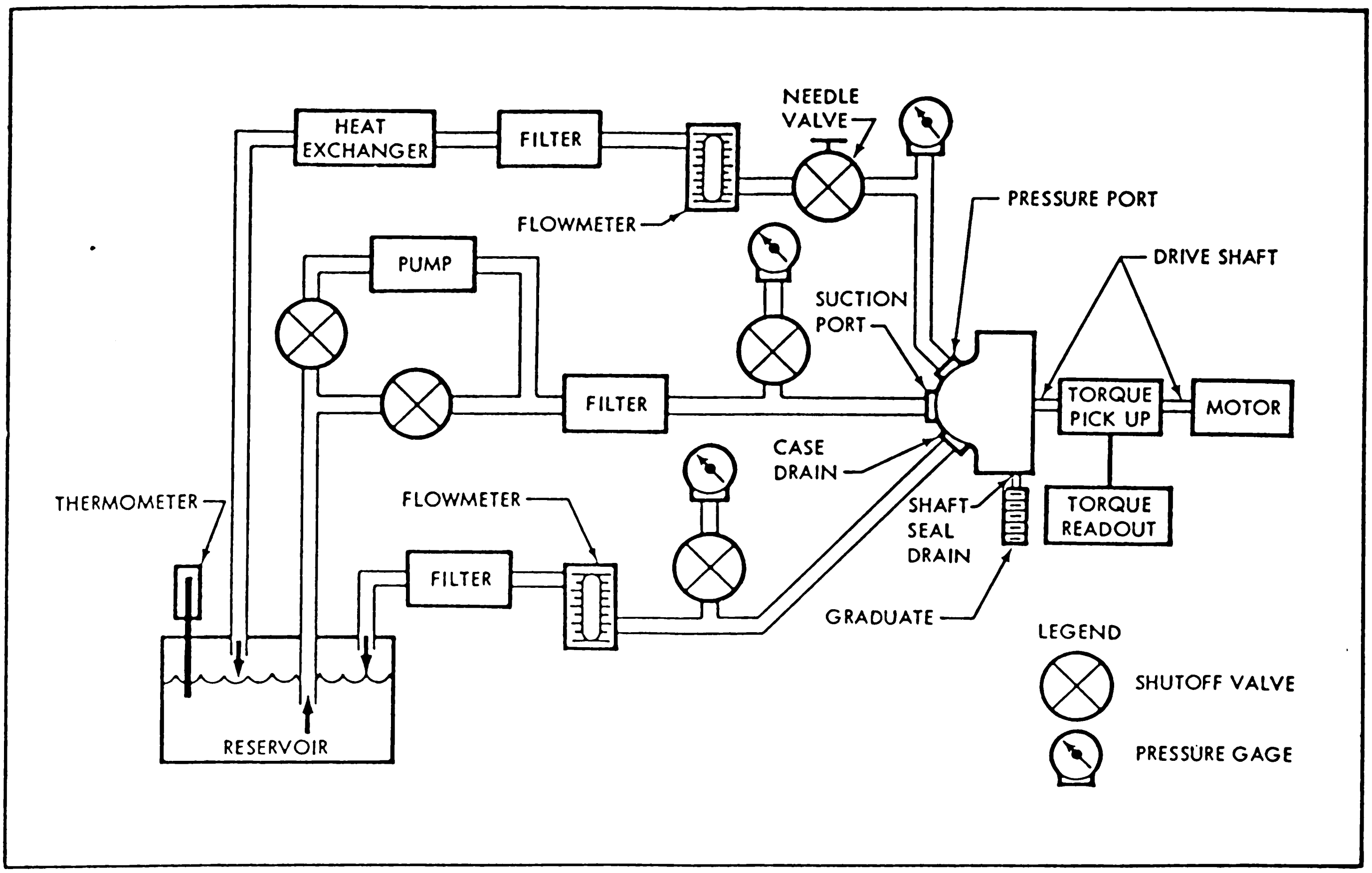

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Figure 1–7. Hydraulic pump test circuit.

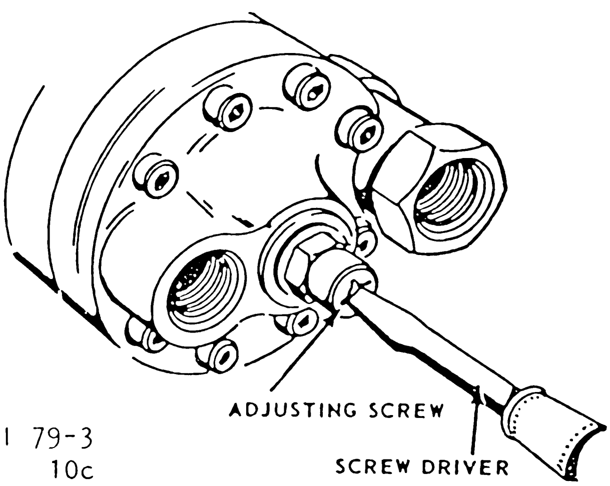

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Figure 1–8. Adjusting pump compensator.

flow meter in the pressure line. The pressure line pressure gage will read zero as long as the needle valve is open.

Case drain (bypass) test. This test will indicate the amount of case drain leakage of the pump when the pump is running. As you can see, the fluid from the case drain line must pass through the case drain flowmeter.

Drive shaft torque test. The drive shaft torque will be used to indicate the amount of torque required to turn the pump drive shaft at a specified rpm, with the pump at zero flow.

Static pressure (shaft seal) test. While you were testing the pump, you should have been looking for external leakage. Another way of checking for leakage is by disconnecting all the lines to the pump and plugging the pressure and suction ports. Next, connect a pressure source to the case drain line. Pressurize the pump (approximately 150 psi but not to exceed TO limits) and check for external leakage, especially around the shaft seal. Remember, these tests are general in nature and by no means do they include all tests that may be performed on a particular engine-driven pump.

Exercises (608):

1. When you check the pump for full flow, what position should the pressure line shut-off valve be in?

2. Which of the tests stated in the text would you use when adjusting the pump pressure?

3. In what position should the pump pressure line needle valve be placed when you check the torque on the drive shaft torque meter?

4. To which port should pressure be applied when you check the pump using the static pressure test?

609. Specify the procedures to use when bench checking and repairing an accumulator.

Bench Check and Repair of Accumulator. One of the items that you may frequently have problems with is the system accumulator. Since the principle of operation is very simple, accumulators do not generally malfunction mechanically; but they are known to leak both internally and externally. Let's assume that the accumulator in the system is found leaking internally. You remove it and take it to the shop for repair. (Caution: Insure that the air pressure has been released prior to disassembly.) During disassembly install the accumulator in a suitable holding device. The holding device should be designed so that it encases with nearly equal tightness the entire circumference of the accumulator shell. Uneven tightness such as vise jaws could distort the shell. Disassemble the accumulator in the sequence of index numbers assigned to the exploded view in figure 1-9. If the identification band (12) is removed, it must be kept with the unit from which it was taken; it bears the serial number and part number. Now clean all metal parts in the proper cleaning solvent specified in the technical order. Dry the parts thoroughly with filtered, compressed air. After cleaning, inspect the inside diameter of the shell (13) and outside diameter of the piston (10) for scratches, burrs, or other damage which would affect the free sliding action of the piston in the shell. Inspect the shell, piston, retainers (4), and end caps (2 and 3) for cracks, deformation, or any other structural damage. Check threads for condition. Conduct a nondestructive inspection of the end caps using fluorescent penetrant inspection. Inspect the shell using magnetic particle inspection. After inspecting the various components of the accumulator, repair or replace them as necessary. Do not attempt, though, to repair the inside diameter of the shell because low spots can affect the operation. Replace all seals and backup rings at each overhaul regardless of condition. During reassembly lubricate the inside diameter of the shell, ring grooves, packings, and piston with a light coating of hydraulic fluid. Then, reassemble the various components in the reverse of disassembly except as noted below. With new packings and backup rings on the piston carefully insert the piston into the shell. Install the retainers (4) into the end caps (2 and 3) with screws (5), and safety wire. Carefully screw the shell (13) into the end caps (2 and 3), making sure that the face of the piston (10) is toward the hydraulic end cap (2). Install the half mounting rings (1) and the identification band (12). If a new identification band is installed, transfer all identification data from the old band. After reassembly you should test the unit to insure that it is functioning properly. There are several tests that should be performed, including the piston seizure test, proof pressure test, and internal and external leakage tests. Let's begin by preparing the accumulator for testing. This will require a source of nitrogen (or dry air) capable of supplying pressure from 0 to 3000 psig. Exercise extreme caution when performing tests with high pressure nitrogen or air. Also, a source of hydraulic pressure from 0 to 6000 psig will be required. Tests should be performed using the fluid for the system in which the accumulator is to be installed, if known. This will prevent contamination of the system.

Piston seizure test. Determine the position of the piston (10) with respect to the end caps (2 and 3). Connect a pressure source to the end cap (2 or 3) nearest to the piston (10). Slowly apply pressure, not in excess of 50 psig, to the accumulator until the piston moves the entire length of the shell (13). Check to see if there is any evidence of seizing or binding. Now connect the pressure source to the opposite end cap of the accumulator and repeat procedure outlined above. If more than 50 psig pressure is required to move the piston during any part of the test, an improper fit or damage to surfaces of the piston or shell is indicated. After completion of the test, connect pressure source to the end cap nearest the piston and apply pressure to move the piston to the approximate center of the shell.

Proof pressure test. With the accumulator piston positioned in the approximate center of the shell, fill the hydraulic end and gas end of the accumulator with hydraulic fluid. Plug one of the end cap ports and connect the other to the hydraulic fluid source. A pressure gage capable of indicating pressure from 0 to 6500 psi should be installed in the line from the hydraulic pressure source to the accumulator. Be certain that all air is removed from the accumulator and that the connecting lines, and fittings, are capable of withstanding the proof pressure and hold for 5 minutes. There must be no external leakage, evidence of damage, or deformation. As you can see, the hydraulic pressure source will force against the piston, which will build up pressure on the opposite side of the piston. This way the accumulator can be proof pressure checked by applying pressure to only one side of the accumulator.

Internal leakage test. Remove the plug in the hydraulic end cap and position the piston so that it bottoms against the hydraulic end cap (2). Mount the accumulator upright with the hydraulic end cap on top and open to the atmosphere.

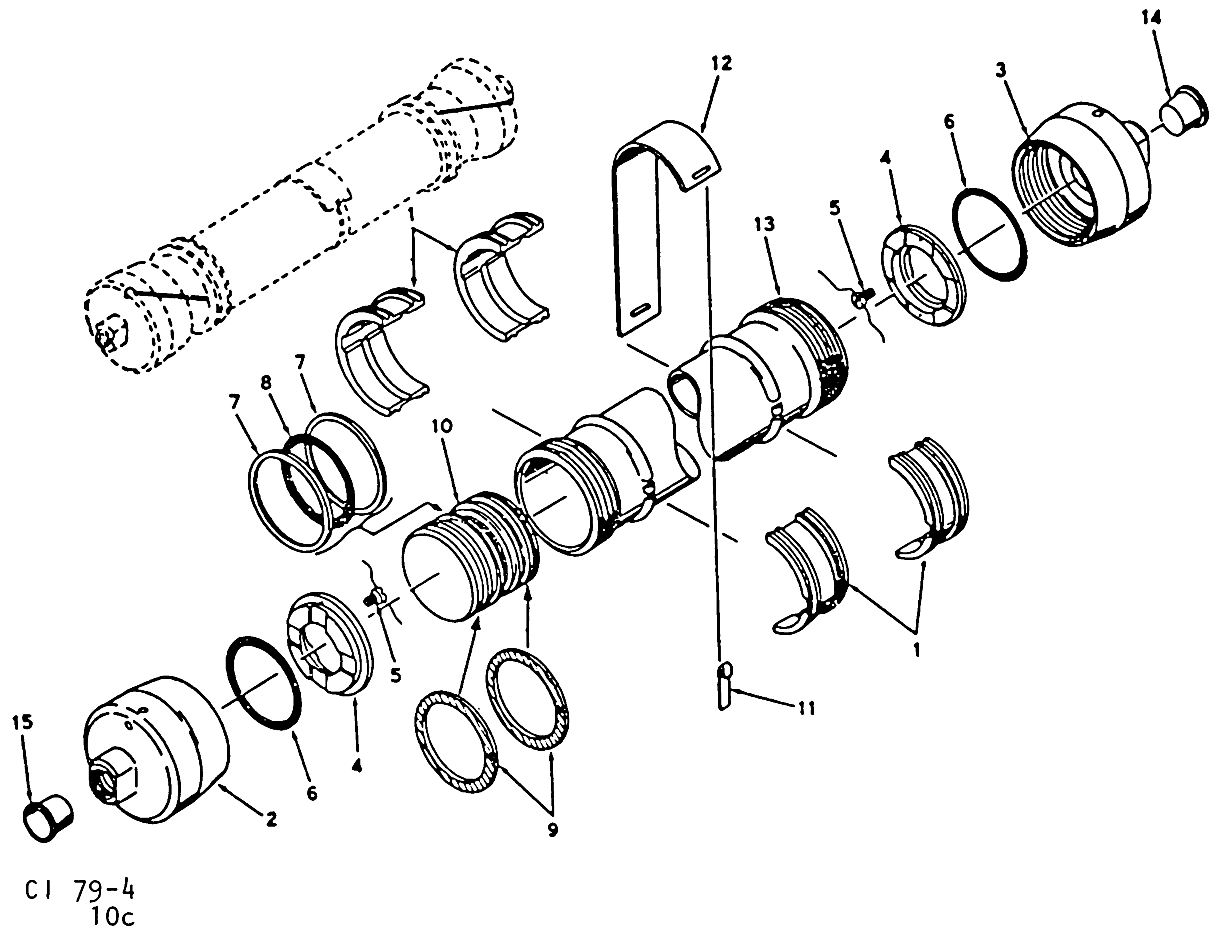

Figure 1-9. Accumulator breakdown.

Fill the fluid port to an overflowing condition with hydraulic fluid. Now apply approximately 200 psig to the gas end cap and hold for three minutes. Check for air bubbles from the hydraulic end cap, which will indicate internal leakage of the accumulator. Increase the pressure to 2000 psig and maintain for 3 minutes also. Here again, check for leakage at the hydraulic end cap.

External leakage test. After completion of the internal leakage test, drain the accumulator of fluid. Connect a nitrogen (or dry air) source to both hydraulic and gas ports. Then, submerge the accumulator completely in water. Apply approximately 200 psig pressure to the hydraulic and gas ports simultaneously. Maintain pressure for 5 minutes while observing water for evidence of leakage as indicated by air bubbles. Check to see if there is any evidence of external leakage. Allow trapped air to escape before starting 5-minute test period. Increase the pressure to approximately 3000 psig and maintain pressure for 5 minutes. Check again for evidence of air bubbles. Ignore the escape of trapped air while increasing the pressure from 200 to 3000 psig. After completion of testing, drain accumulator of excess hydraulic fluid; plug gas and hydraulic ports, and safety wire the end caps.

Exercises (609):

1. Prior to disassembly, what precaution should you take?

2. Other than by visual inspection, how else can defects in the accumulator be detected?

3. You find that while performing the piston seizure test the piston does not move freely. You know that the accumulator was working properly before you took it off the aircraft except that it was leaking externally. What could have happened to cause this malfunction?

4. Does it make a difference which way the end caps are installed on the shell of the accumulator? Explain.

5. From the tests described in the text, how would internal leakage be detected?

Landing Gear and Related Systems

SOME CARGO aircraft weigh around a quarter of a million pounds without a pound of cargo on them. What do you suppose would happen if the landing gear on such a fully loaded aircraft collapsed as it touched down? The cleanup crew would have quite a job on their hands.

Specifically, what does a landing gear do? At least five things. First, by means of gear retraction mechanisms, it attaches the landing gear to the aircraft structure to enable the gear to extend and retract safely. Second, by means of shock struts, it reduces the shock of landing and taxiing, thus reducing damage to the aircraft structure. Third, by means of a nosewheel steering system, it provides directional control of the aircraft during ground movement. Fourth, by means of a brake system, it stops the aircraft. Fifth, by means of the arresting gear, the aircraft can be stopped if the brakes should fail. You can see, then, that landing gear systems are quite important to aircraft operation.

You perform many duties in maintaining the various systems that comprise an aircraft's landing gear. These duties include: operational checks of the landing gear, brakes and steering systems, and system components. You also perform servicing requirements. Additionally, you remove and replace such components as steering units and brake assemblies. These are the items covered in this chapter. To help fill out the knowledge needed and accomplish your duties, begin by reviewing the arrangement of the landing gear.

2-1. Landing Gear Systems and Components

In the early days of aviation, an aircraft landing gear consisted of two fixed main gears (nonretractable) and a skid undertail assembly. This type of gear was adequate, since these aircraft were slow and rather light. Then, in an attempt to obtain more speed, the gear was first streamlined to cut down on the amount of drag. This helped some; but being ambitious, dissatisfied, and ingenious, the engineers came up with the retractable-type gear. This was a tremendous improvement in drag reduction. Yet, of course, we did not get something for nothing; and, in this case, the weight was increased by the necessary extra linkage and retracting system. As aircraft became faster and heavier, more and more was demanded from the landing gear. But the design engineers have accomplished their goals. Today's aircraft are equipped with sturdy, smooth, and efficiently operating landing gears.

In this section we begin by reviewing the tricycle and quadricycle landing gear systems, then talk about the antiretraction device, position and warning systems. Last, but not least, we cover the arresting hook system.

610. Specify the key operational and structural characteristics of tricycle and quadricycle landing gears.

Landing gears are no longer just a simple set of skids such as the Wright Brothers used on their first aircraft. The state-of-the-art has brought us to the need for much more sophisticated equipment as each new generation of aircraft is developed. Of the various types of landing gear—conventional, bicycle, tricycle, and quadricycle—generally only the last two are used on aircraft today.

Quadricycle Landing Gear. The quadricycle landing gear is used only by the B–52 aircraft. This landing gear might also be called a double bicycle arrangement. It consists of four main gears mounted in the fuselage in the form of a rectangle and two outrigger or tip protection gears, as shown in figure 2-1. The tip protection gears are mounted near the outboard end of the wings to provide for lateral stability during heavy gross weight landings.

Since the quadricycle landing gear is retracted into the fuselage, the main advantage of this arrangement is that it allows for the design of thinner wings. The thinner swept back wing on the B–52 contributes to greater speed. In addition, the position of the main gear units causes the landing forces to be more evenly distributed over the whole aircraft. It also makes use of shorter, yet larger, main landing gear assemblies that, in turn, improve the braking characteristics of the aircraft.

Tricycle Landing Gear. Most aircraft are equipped with the tricycle landing gear. The familiar triangle pattern is not new to most aircraft technicians. The two main gears are usually installed to the right and left of the fuselage centerline. The nose gear is installed at the forward section of the fuselage.

Because aircraft are different in size, shape, and construction, almost every landing gear is of a special design. Even though the gears may be of different designs, the struts of all aircraft having a tricycle landing gear are attached to strong members of the wings or fuselage so that the landing shock is distributed as widely as possible throughout the main body of the structure.

Safety. The old three-point conventional landing gear (two main gear and tail wheel) was all that was available for many years. The problems encountered with it were tolerated because no other choice was at hand. The advent of the tricycle gear system eliminated three of the greatest

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Figure 2–1. Quadricycle landing gear.

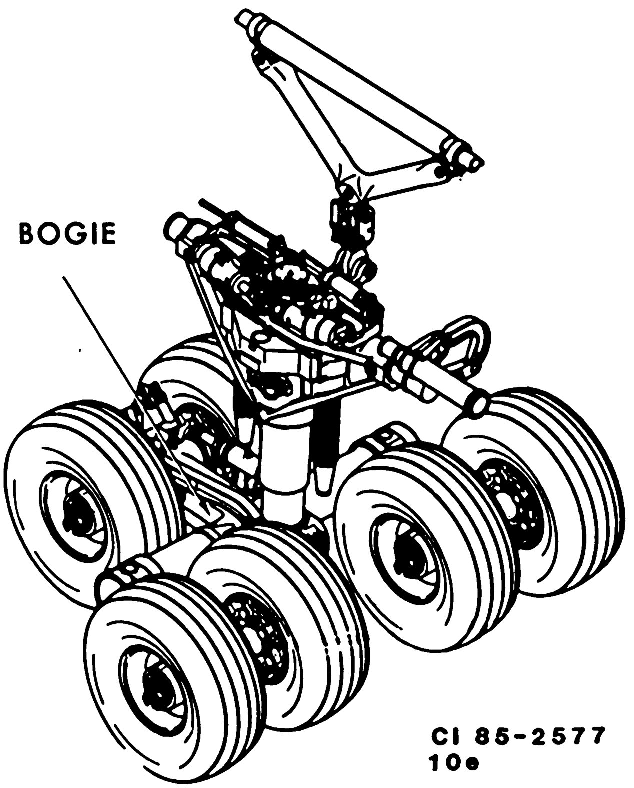


Figure 2–2. Bogie (truck)-type gear.

hazards encountered with the conventional system. First, forward visibility for takeoff and taxiing was improved. Secondly, ground looping was eliminated because of the weight forward conditions of this configuration. The last advantage allowed the hard application of brakes without fear of the "noseover." Later improvements—e.g., antiskid—completely eliminated any irregular patterns in braking during the landing roll.

Aircraft Land-to-Gear Weight Ratio. The trend had been until the early 1950's to increase the strut, axle, and wheel size to accommodate the increasing demand to carry more weight. The advent of multiple axle, bogie (truck)-type main landing gear solved this problem (fig. 2-2). This new design incorporated lighter and stronger strut and axle assemblies and increased the number of tires. Three basic advantages were realized by this hallmark in aircraft engineering.

(1) The gross weight of the aircraft was increased nearly twofold without an appreciable gain in weight of the landing gear.

(2) The tire sizes were reduced to more manageable sizes.

(3) The total weight of the aircraft was displaced over a wider area, thus subjecting runways and taxi areas to less damage.

Exercises (610):

1. What are the two types of landing gear configurations used on aircraft?

2. Why are the main struts of the tricycle landing gear attached to strong members of the wing or fuselage?

3. What advantages are realized by use of the tricycle landing gear design?

4. What design features are used on today's heavy-weight aircraft landing gear to distribute the greater weights?

5. What two problems were eliminated when the truck and bogie assemblies were introduced?

6. Why are tip protection gears provided on a quadricycle landing gear?

7. What does the quadricycle landing gear system consist of?

8. How is the quadricycle landing gear unique?

9. List the advantages of the quadricycle landing arrangement.

611. Specify the purpose and operational features of the antiretraction device.

Gear Antiretraction. In order to operate the landing gear on most of today's modern aircraft, only one manual operation must be performed: to move the gear control handle to either the gear UP position or the gear DN position. In a properly operating landing gear system, everything else is automatic.

To prevent the accidental collapsing of the landing gear while the aircraft is on the ground, most aircraft have some type of antiretraction device. First of all let's see why this device is necessary. Let's say that an aircraft is at the end of the runway ready for takeoff. The landing gear lever is down, the engines are running and hydraulic pressure available to all the subsystems including the landing gear system. Now let's say the pilot accidently drops his or her check sheet on the floor—just below the landing gear lever. He or she reaches down to pick it up and without knowing it moves the landing lever to the UP position. With both electrical and hydraulic power available, the landing gear collapses. The aircraft engineers needed to come up with a way to avoid this problem. They decided that since the aircraft struts are compressed while the aircraft is on the ground and extended in flight, they could install a switch that would prevent accidental gear retraction. This switch has been called many names: *touch down, safety* and *scissors,* just to name a few. Basically it opens the electrical circuit to the landing gear control valve—at least until the aircraft is airborne. Even if the landing gear lever is accidently moved from DOWN to UP while the aircraft is on the ground, the safety switch prevents the gear from retracting. Another way of preventing the landing gear from retracting is to install a lock on the landing gear lever itself. Figure 2-3 shows a simple antiretraction electrical circuit for this lock. Notice that power can flow from the 28V bus through the solenoid, safety switch, and then to ground. The lockpin is extended by spring tension and retracted whenever the solenoid is energized. The landing gear control handle cannot be positioned unless the lockpin is moved out of the way. When the strut is compressed (the aircraft is on the ground), the safety switch is open and the spring forces the lockpin toward the control handle. As the weight of the aircraft leaves the struts during takeoff, the safety switch closes to complete the electrical circuit. The solenoid energizes and unlocks (pulls) the lockpin away from the control handle allowing the pilot to position it to raise the gear. Now ask yourself what will happen when the antiretraction electrical circuit should malfunction or you want to move the landing gear control handle without electrical power. As you can see, the spring forces the locking pin toward the control handle to prevent the handle from moving. The engineers of this aircraft thought this might happen, so they installed a lock release finger latch,

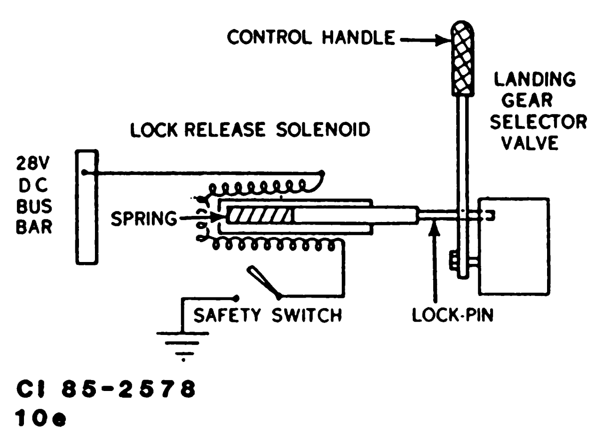


Figure 2-3. Simple antiretraction circuit.

shown in figure 2-4. By pulling the lock release finger latch down, it compresses the spring behind the lockpin and allows the landing gear control lever to be positioned.

Exercises (611):

1. Why is the antiretraction device installed on aircraft?

2. If the gear is in the air, in what position is the lockpin on the antiretraction device?

3. When the aircraft is on the ground, is the antiretraction electrical circuit complete or open?

4. If you wanted to raise the landing gear lever while the aircraft is on the ground, what must you do?

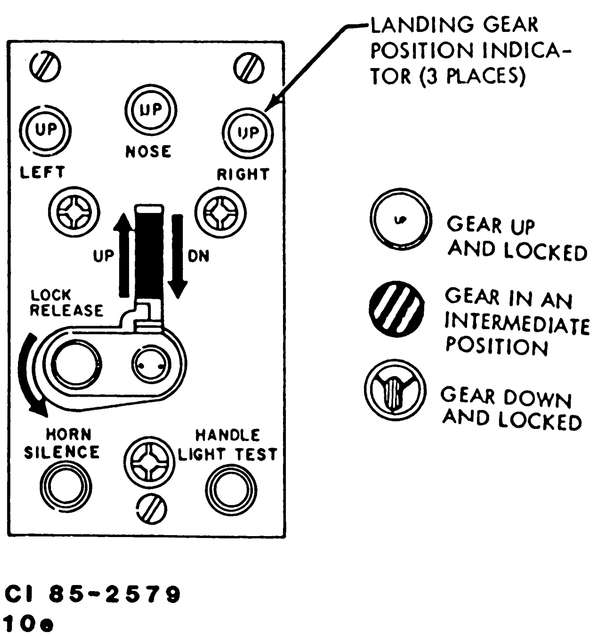


Figure 2-4. Landing gear control panel.

612. Specify warning indications relevant to the operation of the landing gear position and warning system.

Position Indicators. Several designs of gear position indicators are available. One type consists of three green lights that burn when the gear is down and locked. Any other time, the lights are out. A second type uses electrically operated selsyn indicators that show a picture of the gear position (fig. 2-4). When any gear is down and locked, a picture of a wheel appears in its indicator window. When any gear is up and locked, the word "UP" appears in the corresponding window. When any gear is neither locked up nor down, a picture of a barber pole appears in the window.

Gear Warning Devices. Warning devices usually consist of a warning horn and a red warning light located in or near the landing gear control handle. The warning light will come on whenever any gear is between the DOWN or UP and LOCKED position. The warning horn will come on whenever the pilot forgets to lower the gear during landing procedures. Depending on the type of aircraft, there are several situations that could cause the warning horn to sound—the throttles retarded, flaps lowered, or air speed too slow to maintain controlled flight.

This tells the pilot to either lower the gear for landing or increase air speed. If the pilot decides not to do either of these things, he or she can push the warning horn silence button that silences the warning horn.

Landing Gear Warning System Operation. Now that you are familiar with the units in the warning system, let's see how it works. Let's start with what the pilot sees during takeoff.

During takeoff, all three position indicators should show a picture of a wheel, and the warning light should be out. Shortly after takeoff, the pilot places the landing gear control lever in the UP position. As the first gear breaks away from its DOWN and LOCKED position, the position indicator moves from the picture of the wheel to the barber pole position. The red warning light also comes on. When the gear gets to the full UP position, it positions the position indicator from barber pole to UP. The red warning light goes off when the last gear is up and all the doors are closed.

When the pilot decides to land, this is what happens. After slowing down to where the slipstream will not do structural damage, the pilot can lower the gear. Up to this time, the pilot should not have any warning light indication, and the position indicator should indicate UP. The pilot places the landing gear control handle to the DOWN position, and the gear begins to move downward. The red warning light will glow when the first wheel well door is opened, and the gear position indicator will move from the UP position to a barber pole position. These two items indicate to the pilot that the gear is unsafe. As each gear locks down, the position indicators will show a wheel. When all three of the gears lock down, the red warning light automatically goes off, allowing the pilot to know it is safe to land.

Exercises (612):

The following questions are referenced to a landing gear warning system that uses a selsyn position indicator.

1. If the gear is between full UP and full DOWN, what position is shown on the position indicator?

2. When will the warning horn come on?

3. How can the warning horn be silenced?

4. When is the red warning light on?

5. The pilot just placed the landing gear handle down, the left main gear locked down, but the right main gear stayed locked in place, and the nose gear is hanging between the full UP and DOWN position. What indications will the pilot receive to show that the gears are unsafe?

613. Specify the constructional/operational features of a large aircraft landing gear system.

Large Aircraft Landing Gear System. The landing gear system we shall talk about has four main gears that are hydraulic motor driven through a gearbox in order to raise and lower the gear. It also has a nose gear strut that is raised and lowered by an actuating cylinder.

The main gear system, as shown in foldout 3, consists of four wheels. Each wheel has a separate strut. The struts are attached to jackscrews that are connected to a gearbox for each pair of struts. A hydraulic motor attached to each gearbox raises or lowers the gear. The hydraulic system supplies fluid under pressure through a landing gear control valve to each of the two landing gear hydraulic motors.

A one-way flow regulator in each line controls the flow of hydraulic fluid from the motor to return. Note that a controllable restrictor valve is in the up line. Through a bellcrank, a lever arm on top of each main landing gear front strut mechanically actuates this controllable restrictor valve just before the gear reaches its fully retracted position. This action closes the valve opening so that it becomes a small orifice. As a result, gear retraction for the final travel is slowed. The shuttle valve is installed to direct the pressure to the spring-loaded brake attached to each gearbox. The brake lock holds the landing gear in the UP position until the operator releases it, either by hydraulic pressure or by mechanical means. When the airplane is on the ground, a friction washer on each jackscrew (not shown) assembly serves as a downlock. As the main gear extends and retracts, mechanical linkage between the aft main landing gear struts and the doors (not shown) causes the door to open and close.

The nose gear consists of a single strut that is raised and lowered by a hydraulic actuating cylinder. The nose gear is locked in the DOWN position by an internal lock built into the actuating cylinder itself. When the nose gear is up, it is held in the UP position by an uplock cylinder.

A two-way flow regulator in the up actuation line, upstream of the nose landing gear actuating cylinder, restricts the flow of hydraulic fluid to and from the cylinder. A shuttle valve connects the pressure down line to the emergency system pressure. The emergency extension valve is connected to the emergency hydraulic system (hand pump) to lower the nose gear in emergency.

Normal gear retraction. Assume that the pilot has just taken off, and the pilot places the landing gear control handle in the UP position. As long as the sequence switches on any of the gears are like those shown in foldout 3, the selector valve can be energized, because the ground for the up solenoid is made through these switches. With the solenoid energized, the selector valve is positioned to admit hydraulic pressure to the up lines. As pressure flows to the nose gear actuator, it raises the nose gear. Also notice that the pressure is available to the nose gear uplock actuator. As the nose gear reaches the UP position, the uplock locks the gear in the UP position. The ground in the uplock switch will be broken when the uplock is completely locked. Notice that the solenoid-operated valve still has a complete ground through the other main gear sequence switches. At the same time that pressure was available to the nose gear, it was also available to the main gear. Notice that the pressure flows through a shuttle valve to the gearbox brake. The pressure releases the brake. Now notice that pressure flows to the landing gear motor that turns the gearbox to retract the gear. When the main gears are all the way up, the switches are broken and the selector valve is deenergized. When this happens, the gearbox brake will lock the gear in the UP position.

Normal gear extension. To lower the gear, the procedures are basically the same as the retraction. The landing gear lever is placed in the DOWN position, but notice that the power goes directly to the control valve and to ground. When this happens, the selector valve is positioned as shown in foldout 4. Pressure is available to release the nose gear uplock and push the nose gear to the DOWN position. Pressure is also available to release the brake on the main gear, which allows the hydraulic motor to extend the gear.

Emergency main gear extension. Emergency methods of actuating the main landing gear mechanically or manually are accomplished by engaging the yellow emergency handles, two extension stub shafts, and two handcranks.

To free the mechanism and prevent damage to equipment and personnel, deplete all hydraulic pressure before actuating the emergency system. The emergency engaging handles are connected by cables to their respective gearbox assembly. Pulling an emergency engaging handle releases the gear brake mechanism and engages the manual extension and retraction gears. A handcrank is then used to operate the appropriate extension stub shaft. The shaft is

connected by mechanical linkage to the gearbox assembly that drives the screwjacks.

Emergency extension of nose gear. To lower the nose gear in emergency, the NLG emergency extension valve must be placed in the EMERGENCY position. When the selector valve is in this position, emergency pressure may be used to unlock the nose gear uplock. When this happens, the nose gear free falls, but may not lock down completely. In order to insure that the nose gear is locked down, the emergency pressure is also sent to the extend side of the nose gear actuator. When the gear is all the way down, the down lock in the nose gear actuator will lock the gear down.

Exercises (613):

1. When the landing gear control lever is placed in the DOWN position, does it matter what position the sequence switches are in? Explain.

2. What units raise and lower the main landing gear during normal operation?

3. What unit will lock the main gear in the UP position during normal operation?

4. How is the main landing gear operated when no hydraulic pressure is available?

5. What precaution must you take before extending the main gear by emergency procedures?

6. How is the nose gear locked in the UP and DOWN positions?

7. How is the nose gear uplock released when the normal hydraulic system is inoperative?

8. What unit in the nose gear system restricts the flow of fluid to and from the gear actuating cylinder?

9. What unit in the main landing gear system directs pressure to the spring-loaded brake attached to each gearbox?

10. In the nose landing gear system, what unit connects the pressure down line to the emergency system pressure?

614. Cite the normal and emergency operational characteristics of a fighter-type aircraft landing gear system.

Fighter Aircraft Landing Gear System. The main landing gear system, as shown on foldout 5, includes the mechanical units of the gear, a hydraulic system for normal extension and retraction, a pneumatic system for emergency extension, and an electrical system for gear control and position indication. Let's discuss the operation of the landing gear system.

Operation. For normal operation of the system, electrical power and hydraulic power must be applied.

Retraction cycle. Retraction of the landing gear is initiated by placing the landing gear control handle in the GEAR UP position. To energize the gear up solenoid of the landing gear selector valve, 28-volt DC electrical power follows a circuit through the control switch (in control handle), the main gear scissors switches, the nose gear limit switch, and the main gear inboard door close limit switch. Energizing the valve directs hydraulic fluid under pressure from the hydraulic system to the gear up side of the landing gear hydraulic system. At the same time, the gear down side of the system is connected to the hydraulic system return.

The hydraulic fluid pressure directed to the gear up side of the landing gear hydraulic system unlocks the integral down locks (locks that are built internally in the actuator) of the nose gear drag brace actuator to begin gear retraction. As the down limit switches on each actuator break contact, the landing gear warning light illuminates, and the landing gear indicators show barber poles.

As the main gear strut reaches several degrees from the UP position a pin on the strut fork engages the uplock hook on the uplock support fitting and causes the hook to rotate. The rotation actuates the hydraulic sequence valve and allows hydraulic fluid under pressure to flow to the uplock actuator. The actuator moves the hook that raises the gear to the UP AND LOCKED position. Hydraulic fluid is directed by the sequence valve to the inboard door actuator through a restrictor. The restrictor allows the inboard door operation overlap. The outboard door is closed mechanically by a link between the strut and the door. The inboard door mechanism actuates a limit switch and causes the indicators for the main landing gear to show the UP AND LOCKED status.

When the nose gear strut reaches a position near the uplock yoke, a roller on the drag brace actuator engages the arm on the uplock sequence valve. Actuation of the sequence valve allows hydraulic fluid under pressure to flow to the uplock actuator that actuates the uplock mechanism. The uplock mechanism raises and locks the strut in the UP position and closes and locks the aft door by means of mechanical linkage. As the gear reaches the UP AND LOCKED position, the nose gear up limit switch and

the main gear inboard door close limit switches are actuated. Actuation of the switches deenergizes the selector valve solenoid to relieve hydraulic pressure to the gear up side of the system. Actuation of the switches also causes the warning light in the control handle to go off and the position indicators to show UP.

Extension cycle. The extension cycle of the landing gear is essentially the reverse of the retraction cycle. Placing the landing gear control handle to GEAR DOWN position energizes the gear down solenoid of the landing gear selector valve. This valve directs hydraulic fluid under pressure to the gear down side of the landing gear hydraulic system and connects the gear up side of the system to return.

On the main landing gear, hydraulic fluid pressure is directed simultaneously to the side brace actuator and the inboard door actuator. The side brace and uplock actuation is retarded by restrictors in the hydraulic system return lines. The inboard door opens first. When the door opens, the door close limit switch is actuated, the indicator in the forward cockpit shows a barber pole indication, and the landing gear warning light comes on. The motion of the side brace actuator is also retarded initially by the piston covering the inlet port to reduce port area. Reduction of the port area allows the uplock mechanism to unlock the strut before there is appreciable motion of the gear. As the side brace actuator locks into the DOWN position, the down limit switch causes the gear position indicator to show a DOWN AND LOCKED position.

During the nose gear extension cycle, hydraulic pressure is applied simultaneously to the gear down sides of the drag brace actuator and to the uplock actuator. Partial coverage of the drag brace actuator pressure port by the piston allows the uplock mechanism to operate first. When the uplock mechanism is forced overcenter by the lock actuator, allowing the gear to extend, the up limit switch is actuated, causing the indicators to show barber poles. As the drag brace actuator locks in the DOWN position, it actuates the nose gear down limit switch, causing the indicator to show a DOWN AND LOCKED position. When all three switches are actuated, the landing gear warning light goes out.

When the gear is compressed by the weight of the aircraft the scissor switches are actuated. Actuation of the switches breaks the electrical circuit from the landing gear control handles to the gear up solenoid of the landing gear selector valve. This prevents the valve from changing to the UP position, even though the landing gear control handle is moved to the GEAR UP position. Thus, the gear cannot be raised when the weight of the aircraft is on the gear.

Emergency extension. When the landing gear control handle in either cockpit is pulled aft, the landing gear emergency pneumatic selector valve opens. This allows compressed air from the emergency air bottles to discharge through the pneumatic lines and shuttle valves to the landing gear system actuators. The high-pressure air actuates the pressure-operated dump valve to dump all hydraulic fluid from the up side of the system overboard. Emergency air pressure is applied to the main gear uplock actuators, main gear side brace actuators, main gear inboard door actuators, nose gear uplock actuator, and nose gear drag brace actuator. Then, the landing gear extends as in normal sequence. The warning light and position indicators also operate as in normal sequence.

Exercises (614):

1. What prevents the gear from retracting while the aircraft is on the ground?

2. How are the gear doors sequenced?

3. How are the gears locked down?

4. When all the gears are fully up and locked, is the selector valve energized or deenergized?

5. When the emergency system is actuated, what happens to the fluid in the landing gear actuator? Explain.

6. During the nose gear extension cycle, to what two areas is hydraulic pressure applied simultaneously?

7. During the nose gear retracting cycle, what component raises and locks the strut in the UP position and closes and locks the aft door by means of mechanical linkage?

8. During the retraction of the main gear, a pin on the strut lock engages the uplock hook and causes it to rotate. What happens as the uplock hook rotates?

9. When will the landing gear warning light illuminate?

10. During main gear retraction, what causes the uplock hook to rotate?

11. During main gear retraction, what unit allows the inboard door operation to lag behind uplock?

12. During nose gear retraction, how is the aft door closed and locked?

615. State the purpose of an arresting hook system and specify its constructional and operational features.

Arresting Gear System. The arresting gear system, shown in figure 2-5, selected for this discussion, is used to halt the forward motion of the aircraft if wheel brakes, speed brakes, and drag chute fail to do so. When extended, the hook in the arresting gear system will engage a cable barrier at the end of the runway. This arresting hook is held against the runway by an air-oil pressurized vertical damper cylinder and dash pot and may be retracted by pressurized hydraulic fluid. Barrier cables are designed to bring aircraft to a gradual stop. Since this is usually the last possible means of stopping an aircraft, it is extremely important to keep the arresting gear system free of troubles.

Operation. The major components in the arresting gear system are shown in figure 2-5. The main unit in this system is the arresting hook, which is located on the underside of the aft fuselage. The hook is pivoted at the forward end, allowing up, down, and sideways motion. Raising and lowering of the hook is controlled by a lever in the forward cockpit. The lever controls the arresting hook uplatch mechanism through mechanical linkage and the control cable. Also, the lever operates an arresting gear control switch to electrically energize or deenergize the solenoid on the selector valve. The selector valve controls the flow of hydraulic fluid to the vertical damper cylinder. Fluid going to and from the vertical damper cylinder is routed through the surge damper. The surge damper prevents hydraulic pressure surges from affecting arresting gear retraction. The hook point is a replaceable unit. The air pressure gage registers the nitrogen charge in the vertical damper cylinder.

Thus far we have talked about the purpose of individual components. Now, let's see how these components operate together to retract the arresting hook. Figure 2-5 shows the arresting gear system components schematically with the control lever in the HOOK UP position and the hook retracting. When the control lever is moved to the HOOK UP position, as shown by the black arrows, the selector valve control switch is activated and energizes a solenoid-operated selector valve. Energizing the solenoid on the selector valve directs hydraulic system pressure by way of the surge damper, through the two-way restrictor, and into the bottom side of the vertical damper cylinder. The hydraulic pressure, acting on the vertical damper cylinder piston, moves the piston up and increases the air-oil pressure above the piston. The upward movement of the vertical damper cylinder piston raises (retracts) the arresting hook.

The arresting hook time delay relay is wired through the hook up limit switch. After an elapse of 1.1 seconds from the time the arresting hook contacts the hook up limit switch, the time delay relay deenergizes the selector valve, relieving hydraulic pressure from the bottom side of the vertical damper cylinder through the surge damper and back to the utility system return line. With the hydraulic pressure relieved, the spring-loaded uplatch mechanism locks the arresting hook in the raised (retracted) position.

Now, let us see how the arresting hook is extended. Movement of the control lever to the HOOK DOWN position removes tension from the arresting hook control cable, releasing the spring-loaded uplatch mechanism.

Also, this movement of the control lever opens a circuit in the selector valve control switch. Opening this circuit causes the solenoid-operated selector valve to spring open. This allows trapped hydraulic fluid in the bottom of the vertical damper cylinder to free flow through the two-way restrictor, the surge damper, and then into a return line back to the utility hydraulic system. After the trapped hydraulic fluid is released, the air-oil pressure in the top of the vertical damper cylinder and the weight of the arresting hook cause the hook to extend. The speed at which the hook extends is controlled by the two-way restrictor. In addition, movement of the control lever to the HOOK DOWN position releases the hook up limit switch, which illuminates the warning light in the control lever.

Exercises (615):

1. What is the purpose of the arrestor hook?

2. What is the purpose of the arresting gear selector valve?

3. How is the hook held in the UP position?

4. What causes the hook to extend when the hook is released from the uplock?

5. What unit prevents hydraulic pressure surges from affecting arresting gear retraction?

6. How is the spring-loaded uplock mechanism released?

7. What controls the speed at which the arresting hook extends?

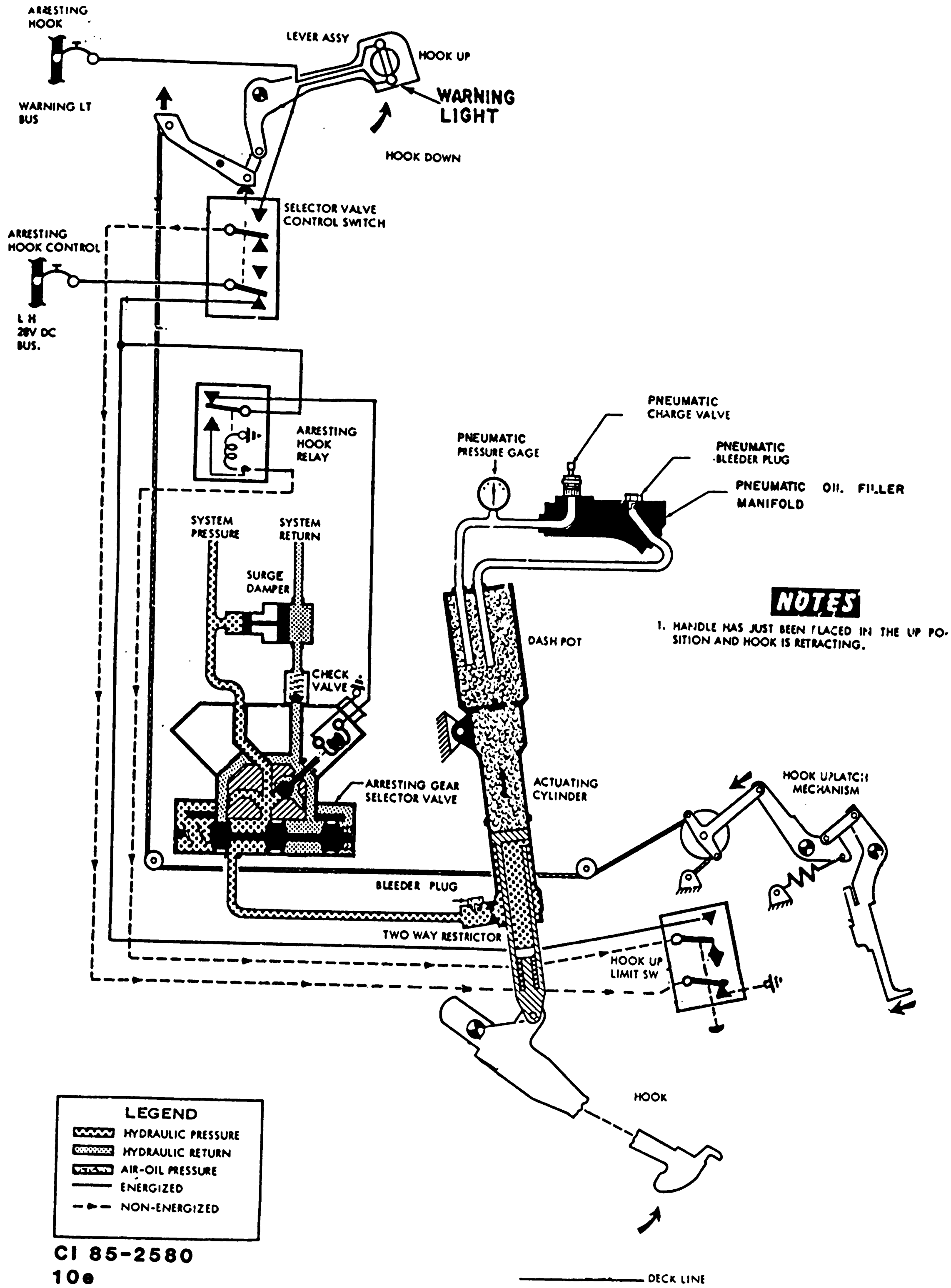


Figure 2–5. Arresting (tail hook) gear.

8. How long will it take before the selector valve is deenergized and relieves hydraulic pressure from the bottom of the vertical damper cylinder?

2-2. Nosewheel Steering

The use of nosewheel steering and damping systems makes it possible to steer aircraft in confined areas without creating the usual disturbance or problems that stem from accelerating the engines or applying the brakes. The resultant longer life of engines and brake linings on aircraft using nose steering and damping systems justifies their use.

Pressure from the aircraft hydraulic system is used to turn the nosewheel either left or right, depending on the pilot's selection. Also, the type of aircraft determines if the system is operated manually (mechanically) or electrically. In this section we talk about the construction and operation of these two types of nosewheel steering systems.

616. Specify the constructional/operational features of a cable-operated nosewheel steering system.

Cable- (Mechanically) Operated Nosewheel Steering System. Most larger type aircraft use a cable-operated steering system, as pictured in figure 2-6. The steering wheel is cable-connected to a steering collar on the strut. Notice that the rocker arm has pulleys for the cable and is able to pivot and position a metering valve in the steering control valve. The steering actuators can rotate the nose strut steering collar a specific amount, depending on the aircraft involved. Let's see what happens when the steering wheel is turned. At the beginning of a right turn, the cables with the black arrows become tight, and the cables with the white arrows become slack. This action changes the tension on the metering valve rocker arm, causing it to pivot. When the metering valve rocker arm pivots, the metering valve mechanism is positioned to send pressure to the steering actuators to rotate the nosewheel strut assembly. The steering cylinders are double-acting hydraulic actuators. The cylinder barrels are designed to remain stationary, but the piston rods, attached to the steering collar, are moveable. The steering collar is attached to the upper torque link of the strut. The lower torque link is attached to the strut piston. Both torque links are jointed together to provide a mechanical linkage between the steering collar and the lower portion of the strut. Normally, whenever the aircraft is to be towed, the upper and lower torque links can be separated. If the torque links are not separated during towing, the fluid in the steering cylinders would have to transfer from one cylinder to the other. With the torque links disconnected, just the lower portion of the aircraft strut rotates. As the steering cylinders move, notice that the steering collar also moves in a direction that tends to equalize the tension on the cables. This is commonly called a followup action and allows the metering valve to return to center, which stops fluid pressure to the steering actuators once the desired amount of travel has been acquired. The return fluid from the cylinders must flow through the compensator of the steering metering valve. The compensator keeps a certain amount of back pressure in the lines for shimmy damper action.

Exercises (616):

1. If the control wheel is rotated clockwise, which direction will the gear move?

2. When towing the aircraft, why should the torque links be disconnected?

3. What repositions the selector valve to neutral when the gear reaches a desired position?

4. What parts of the steering cylinder are stationary and what parts are moveable?

5. What portion of the strut is attached to the strut piston?

6. What portion of the steering system is able to pivot and position a metering valve in the steering control valve?

617. Cite the function of the components and specify the operational characteristics of an electrically operated nosewheel steering system.

Electrical Nosewheel Steering System Construction. As a mechanic responsible for maintaining the nose gear steering system, you must become familiar with each component. Each electrically operated nosewheel steering system varies in its construction, but you should be able to apply the principles presented here to each system you encounter. Let's begin our discussion with the function of the nose gear steering components. Refer to foldout 6 as we talk about the components and system operation.

The command potentiometer is attached mechanically to the rudder pedals. When the rudder pedals are in any position other than NEUTRAL, a signal is produced that is fed into the differential amplifier (control box). Notice that the potentiometer consists of a wiper arm on a resistance strip.

The followup potentiometer is attached to the power steering unit. The followup indicates the position of the power unit.

The selector valve is a remotely controlled, three-way, two-position single-solenoid operated valve used to direct utility hydraulic pressure to the steering system. Notice the two-way restrictor just below the selector valve. This valve

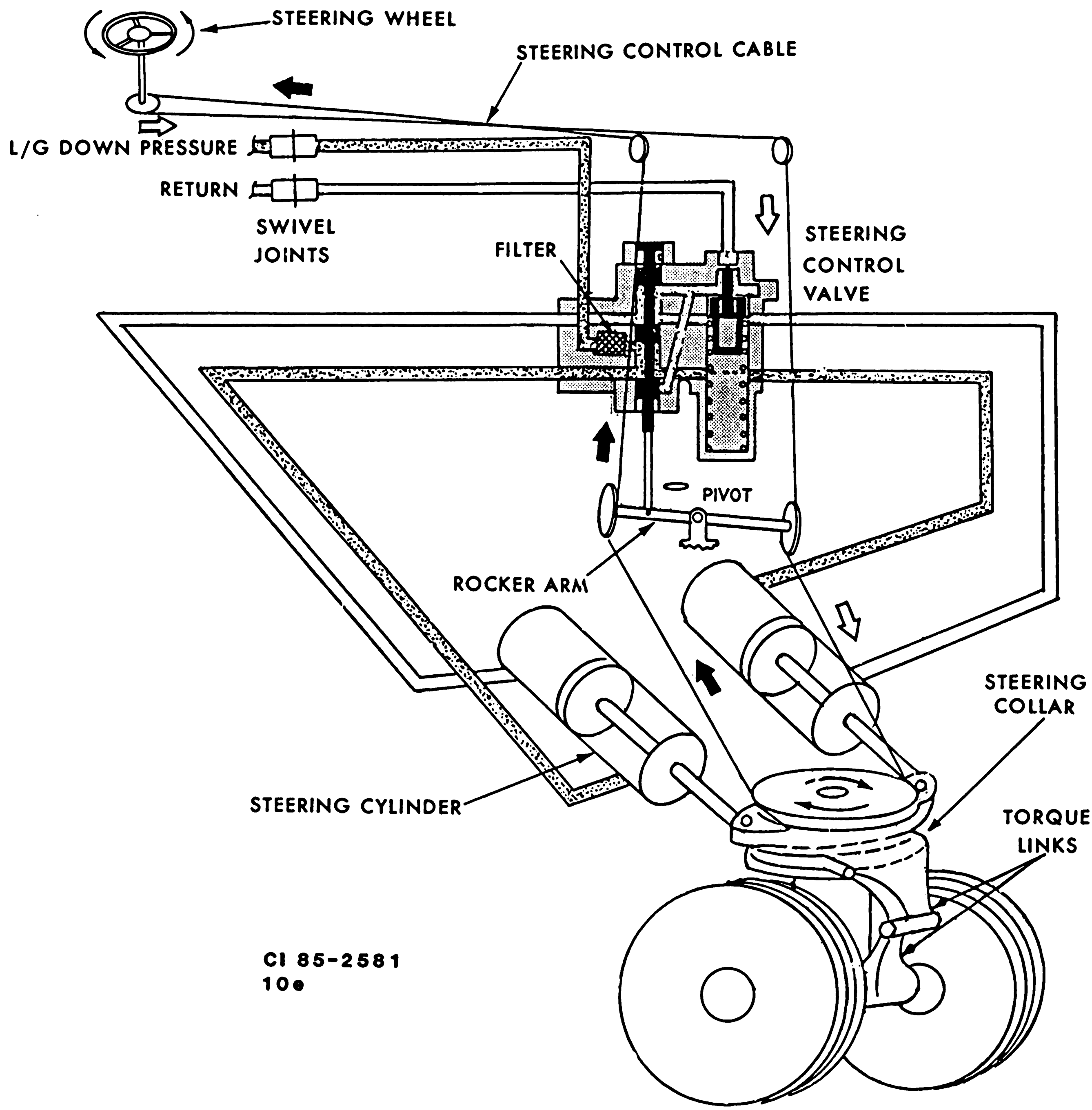


Figure 2–6. Cable-operated nosewheel steering.

is installed in the system to replenish any fluid lost when the selector valve is deenergized.

The power unit is a vaned hydraulic actuator mounted on the nose strut and geared to the strut torque collar. It performs both steering and shimmy damping. A bypass allows hydraulic pressure to flow to the proper side of the steering unit as directed by the servo valve. When the system is deenergized, the bypass valve shifts to trap hydraulic fluid in a channel that connects the hydraulic motor with two one-way restrictors to dampen a wheel shimmy.

When energized, the servo valve sends fluid to one side or the other of the power steering unit. When the power steering unit reaches the desired position, the servo valve is positioned to NEUTRAL, thus blocking the pressure in either side of the power steering unit.

The compensator maintains approximately 300 psi back pressure in the steering unit to prevent cavitation of the vane motor and dampen shimmy when the steering system is not energized. The compensator housing contains two loaded springs that seat against a piston and sleeve and a spring-loaded poppet. Fluid flow is in one direction only: from the power steering unit to return. Return flow from the steering unit displaces the piston and opens the poppet. When the steering unit is deenergized, spring pressure returns the piston and closes the poppet to build up the back pressure in the power unit.

Operation. The nose gear steering system is energized by depressing the nose gear switch on the control stick grip. Before the system can be energized, the gear must be down and locked; and the main landing gear struts must be connected.

When the system is energized, movement of the rudder pedals forward or aft controls the output voltage of the nose gear (input) steering potentiometer. This potentiometer supplies voltage to a differential amplifier in the nose gear steering control unit. The output of the differential amplifier determines which coil in the nose gear steering servo valve receives the most current. The servo valve directs hydraulic fluid to the power unit to turn the wheels right or left. A followup potentiometer sends a signal to the differential amplifier. If an error signal exists between the followup and command potentiometers, the differential amplifier sends current to the servo valve. In turn, the servo valve moves to direct hydraulic fluid to the power unit. In turn, the power unit moves the nosewheels to reduce the error. When the error is corrected, the nosewheels stop at the desired angle of turn. If an open or short circuit occurs in one of the inputs to the control unit, a failure detection network (inside the control box) detects the failure and deenergizes the solenoid in the nose gear steering selector valve. When the solenoid is deenergized, hydraulic pressure is shut off to the steering system. To resume normal operation of the system, the steering switch must be recycled.

Right turn. When the right rudder pedal is moved forward to execute a right turn, the command potentiometer (mechanically linked to the rudder pedal torque tube) sends an increased voltage signal to the differential amplifier. In turn, the amplifier increases the voltage to the right turn coil in the servo valve. The servo valve piston moves and ports hydraulic fluid pressure to the vane motor in the power unit to turn the nosewheels right. As the wheels turn, the wiper arm on the followup potentiometer sends an increased voltage signal to the differential amplifier. When voltage from the followup potentiometer equals voltage from the command potentiometer, the signal is zero and current equalizes in the left and right turn coils of the servo valve. The servo valve then holds the wheels at the desired degree of right turn.

Left turn. When the left rudder pedal is moved forward to execute a left turn, the command potentiometer sends an increased voltage signal to the differential amplifier. The amplifier increases the voltage to the left turn coil in the servo valve. The servo valve piston moves and ports hydraulic fluid pressure to the vane motor in the power unit to turn the nosewheels left. As the wheels turn, the wiper arm on the followup potentiometer sends an increased voltage signal to the differential amplifier. When the voltage from the followup potentiometer equals voltage from the command potentiometer, the signal is zero and current equalizes in the left and right turn coils at the servo valve. The servo valve then holds the wheels at the desired degree of left turn.

Failure detection. The failure detection circuit detects a short, an open, or intermittent signal from the command potentiometer, followup potentiometer, and servo valve. Depressing the nose gear steering switch provides voltage to the control unit power supply and failure detection circuit. If signals from the command potentiometer, followup potentiometer, and servo valve become shorted or open, negative voltage is applied to the detector circuit. In turn, the detection circuit opens the ground circuit to the selector valve solenoid to stop hydraulic fluid to the system.

Exercises (617):

1. What two components control the position of the servo valve?

2. If the electrical system should fail, what will happen?

3. What is the function of the compensator?

4. When the rudder pedals are moved, what do they position?

5. What happens to the servo valve when the signal voltage in the left and right servo valve turn coils is zero?

Look at foldout 6 and answer the following questions.

6. Before the nose wheel steering system could be energized, specify the three items that must be properly positioned.

7. What item energizes the nosewheel steering system?

8. What unit, when the system is deenergized, will shift positions to tap hydraulic fluid in a channel that connects the steering unit with two one-way restrictors?

2-3. Brake Systems

The purpose of a wheel brake is to bring a rapidly moving aircraft to a stop during ground roll. It does this by changing the energy of movement into heat energy through the friction developed in the brakes. It also can be used to park the aircraft.

A feature found in high performance aircraft braking systems is skid control or antiskid protection. This is an important system because if a wheel goes into a skid, its braking value is greatly reduced. The main components of the system consist of skid control generators (detectors), a skid control box, two skid control valves, a skid control switch, a warning lamp, and an electrical control harness.

In this section we will talk about the construction and operation of the two brake systems. The difference between the two lies in the emergency braking system and an antispin system.

618. Specify constructional/operational features of a brake system that induces antiskid and an electrically controlled hydraulically operated emergency system.

Brake System. The braking system provides normal, emergency, and parking brakes. Both the normal and emergency systems are operated by the pilot's and copilot's rudder pedals. The components usually found in a brake system are the power brake control valve, brake assembly, shuttle valves, accumulators, and the shutoff valve, to name just a few.

Antiskid System. The antiskid system prevents wheel locking and skidding. The components in the antiskid system are: Skid detectors, antiskid control valves, and various relay circuits. Besides the normal skid control circuit, the antiskid system may have such circuits as the (1) locked wheel skid control, (2) touchdown protection, and (3) fail-safe protection circuit. A brief description of each of these circuits is covered below.

Locked wheel skid control. The locked wheel skid control causes the brake to be fully released when its wheel locks. A locked wheel easily occurs on a patch of ice due to lack of tire friction with the surface. It will occur if the normal skid control does not prevent the wheel from reaching a full skid.

Touchdown protection. The touchdown protection circuit prevents the brakes from being applied during the landing approach even if the brake pedals are depressed. This prevents the wheels from being locked when they contact the runway.

Fail-safe protection. The fail-safe protection circuit monitors operation of the skid control system. It automatically returns the brake system to full manual in case of system failure. It also turns on a warning light.

Brake System Operation. Regardless of the brake and antiskid system installed on the aircraft, the operation is very similar. Refer to foldout 7 as we discuss brake and antiskid operation.

During operation, downward pressure on the rudder pedal moves the upper brake lever. This movement is passed to the brake control valve. The brake control valve directs hydraulic pressure to the brakes. A normal or emergency brake selector valve determines whether the utility hydraulic system or the auxiliary system pressure is to be used. The brake selector switch selects either normal or emergency operation of the system. When the switch is placed in NORM, the emergency selector valve is energized, and the emergency part of the system is connected to the return. Also, the normal brake selector valve is deenergized, permitting utility hydraulic pressure to be transmitted to the brakes. When the brake selector switch is placed in EMER, the opposite condition exists. Utility pressure is blocked, and the normal brake system fluid is routed to return. Auxiliary pressure then controls brake operation. Shuttle valves at the brake assemblies block off the pressure from the system not in use. If DC power to the brake selector valves fails, both valves are positioned to allow operation from either the utility or auxiliary hydraulic system. The auxiliary hydraulic system handpump can be used for emergency braking, but you must hold the brake pedal down while the handpump is being operated. If you pump the brake pedal, you will bleed away pressure faster than the handpump can be operated. If a wheel tries to skid during braking operations, the antiskid system activates.

The antiskid system works through a brake pressure releasing valve that is controlled by a skid detection element in each wheel. This element detects nonrotation and/or a rapid change in wheel speed. The system is controlled by relays that control the antiskid valve. For example, there are no brakes for 2 seconds or until both locked-wheel detection relays are energized by wheel speed above 15 knots. When the detection relays are energized, a circuit is completed that actuates relays in the safe-braking control boxes. These relays provide remote control of the antiskid valve. The antiskid valve controls the speed by releasing and reapplying brake pressure as the wheels depart from and return to nonskid speeds. The detector speed-sensing circuit causes the brakes to be released on any pair of wheels that has a tendency to begin skidding. When the aircraft has stopped, the speed-sensing circuit becomes ineffective and the brakes remain on.

Included in the antiskid system is a fail-safe circuit. This circuit keeps the brakes from releasing too long because of

antiskid action. If the brakes release too long, there might be insufficient runway for braking to a safe stop. The fail-safe circuit is controlled by a slow release fail-safe relay. This relay prevents continuous release of brake pressure for more than 3.5 seconds. Also, it automatically returns the brake system to normal in case the antiskid system fails.

Exercises (618):

1. Which hydraulic system powers the emergency brakes?

2. What controls the operation of the fail-safe circuit?

3. When the brake selector switch is placed in normal, what brake selector valve is energized and what brake selector valve is deenergized?

4. What unit directs fluid pressure to the brakes?

5. What happens if DC power to the brake selector valve fails?

6. What does the brake skid detection element detect?

7. How are the antiskid valves controlled?

8. What circuit prevents the brakes from being applied during a landing approach?

9. Through what valve does the antiskid system work?

10. Why must you hold the brake pedal down while the auxiliary hydraulic system handpump is being used?

619. Cite the constructional/operational features of a brake system that includes an antiskid system, an antispin system, and a mechanically controlled hydraulically operated emergency system.

Brake Control Units. The brake control units, foldout 8, have two valving portions: one for normal braking and one for emergency braking. An accumulator stores hydraulic fluid under pressure for emergency braking. If utility hydraulic pressure fails, a manually operated emergency brake valve that can be actuated by a T-handle in either cockpit directs fluid from the accumulator to the emergency portion of the brake control valve.

Antiskid System. The antiskid portion of the system consists of an exciter ring and sensor for each of the main gear wheels, a control valve, an on-off switch, disengage switches on the forward and aft control stick, and a warning light.

Antispin System. The antispin system receives hydraulic pressure from the landing gear up line. This pressure is metered through restrictors to the brakes to stop wheel rotation while the gear is being retracted.

Operation. Normal braking is accomplished by depressing the rudder-brake pedals in either the forward or aft cockpit. The antiskid system is turned on or off by a switch located on the pilot's left utility panel. Emergency braking is accomplished by pulling aft on either of the emergency brake handles and depressing the rudder-brake pedals.

Normal braking. During normal braking operation, pressure applied to the brake pedal causes a shift in the piston of the brake control unit. Shifting of the piston causes the return port to close and the pressure port to open. The size of the opening of the pressure port determines and regulates the amount of hydraulic pressure that flows through the control unit and to the individual brakes.

Metered hydraulic pressure from the brake control unit passes through the deenergized antiskid control valve to the wheel brakes. The force acting upon the brakes slows down or stops wheel rotation. When hydraulic pressure is released, the brakes return to their original position to release the braking force.

Antiskid. When the antiskid system is turned on and aircraft speed is above 15 knots, an AC signal is generated by movement of the exciter ring through the magnetic field of the sensor. The generated emf is detected by the antiskid sensor and sent as an input to the antiskid control box. If neither wheel is skidding when brakes are applied, the output of the skid rate detector in the antiskid control box is negative. Therefore, no signal is sent to the control box. In turn, the control box sends a signal to the antiskid control valve, and hydraulic pressure to the brakes remains constant. If either wheel starts to skid while the brakes are applied, a signal is sent to the control box. In turn, the control box sends a signal to the antiskid control valve to reduce pressure to the brakes. Thus, any rate-of-change signal received by the antiskid control valve results in a proportional reduction in brake pressure. As the wheel recovers from a skid, the rate-of-change signal disappears and brake pressure increases correspondingly. Locked wheel and skid protection is removed when aircraft speed is

less than 15 knots to permit low-speed maneuvers and to allow parking.

Emergency braking. If utility hydraulic pressure fails, emergency braking can be applied by pulling the emergency brake handle. Pulling either handle opens the emergency brake manual valve. When this valve opens, hydraulic fluid, stored under pressure in the accumulator, flows to the emergency ports of the brake control units. The accumulator holds enough fluid under pressure for 11 to 13 brake applications. Emergency operation of the control unit is essentially the same as normal operation. Metered pressure from the brake control unit passes directly to a shuttle valve and enters the brake. Note that during emergency operation, hydraulic fluid does not flow through the antiskid control valve. Therefore, there is no antiskid function during emergency braking.

Antispin. Whenever an aircraft first takes off, the wheels will still be spinning at an extremely fast speed. If the gear handle is placed in the UP position, the fast spinning wheels will enter the wheel wells. To prevent this from happening, some aircraft have installed brake antispin systems. Notice the hydraulic line that is coming from the gear up line. Whenever the gear is raised, pressure in the gear up line will flow through the check valves down to the brakes. With pressure applied to the brake, the wheel will STOP spinning as the gear is raised.

Exercises (619):

1. What system is used to apply the brakes as the gear is retracted?

2. What circuit provides a full pressure release signal to the antiskid control valve when both wheels stop rotating?

3. How is normal braking action accomplished?

4. What determines and regulates the amount of hydraulic pressure that flows through the control unit to the individual brakes?

5. How is emergency braking action accomplished?

6. What is the output of the skid rate detector in the control box when the brakes are applied and neither wheel is skidding?

7. Why is there no antiskid function during emergency braking?

8. From where does the antispin system get its hydraulic fluid for operation?

9. When the antiskid system is turned on, how is an AC signal generated?

10. How much fluid is held by the emergency brake accumulator?

11. When will locked wheel and skid protection be removed from the wheels?

2-4. Inspection, Maintenance, and Operational Checks of Landing Gear Systems

In the early days of aviation, the landing gear system consisted of fixed struts with a simple brake system. The job of the pneudraulic specialist, if they had any in those days, would probably have consisted of inspection, removal and replacement of components, and operational checks of the brake system. The pneudraulic specialist of today hasn't advanced very much because the job still consists of inspection, removal and replacement of components, and operational checks. The landing gear systems and components, however, have advanced and have become more sophisticated and complex. We now have landing gear systems that retract and extend the struts, brake systems with antiskid and antispin features, and nosewheel steering. As the requirement for faster and high-flying aircraft increases, the requirement for a more complex landing gear system also increases. This in turn increases the necessity for a superior level of maintenance.

In this section we cover such landing gear systems maintenance areas as inspections, component removal and replacement, and operational checks. It would be impossible in this CDC for us to cover these areas of maintenance on specific systems. We cover what we consider are common maintenance tasks and in some cases use representative examples of maintenance tasks performed on certain aircraft and components.

620. Cite the common inspection requirements of the landing gear and related systems.

Inspection Requirements. The inspection requirements for the landing gear and related systems will differ from one type of aircraft to another. No matter which aircraft you

work on, the details of what to inspect and when to inspect are already laid out for you either on inspection workcards or in the –6 TO. What we have done is combine common inspection requirements for the landing gear and related systems.

Landing gear. One of the first things that enters a person's mind when you say "landing gear" is the struts themselves. The struts should be checked for leakage, corrosion, and signs of damage. The struts should also be checked to insure proper servicing. The lines and hoses should be checked for damage or leakage. The various valves in the system should be checked for security of mounting. The actuating cylinder should be checked for leakage, security of mounting, and proper adjustment.

Nosewheel steering. Since the nosewheel steering is confined primarily to the nose strut, you should check the nose strut for any damage. Check the steering units, actuators, and valves for leakage and security of mounting. Check the hydraulic lines for leakage and damage. Any electrical connections should be checked for cuts or broken wires. If the nose wheel steering system is controlled by cables, check the cables for damage. To insure that they are not broken or cracked, check the cable pulleys.

Brake systems. One of the main items in the brake system is the brake itself. Examine the brake for wear, overheating, corrosion, and leakage. Check the power brake control valve or master cylinder for adjustment, binding, security of mounting, and leakage. Other hydraulic components, such as antiskid valves, shuttle valves, and boosters, should be checked for security of mounting and leakage. Check brake lines and hoses for damage and leakage.

Common inspection items. Besides checking all of the above items in the respective systems, you should also check for missing clamps, nuts, bolts, and washers. Another thing commonly found on inspections is that items are safety wired wrong or not at all. On finding a damaged line you should ask yourself "What could have caused this damage?" Did a rock strike the line, did someone step on it, or is it chaffing another item as the system is operated? Simple removal and replacement of the damaged line is not enough. You could fix the malfunction temporarily, but if the original malfunction is not corrected, it will simply happen again.

Exercises (620):

1. While performing an inspection of the landing gear system, you find a line in the wheel well that is chaffed. What should you do?

2. Cite three inspection items for a landing gear actuator cylinder.

3. Name two things electrical connections should be checked for.

4. Cite four items the brake itself would be inspected for.

5. What are the items a power brake control valve would be inspected for?

6. In a cable-operated nosewheel steering system, what are the cable pulleys inspected for?

621. From given situations, specify the procedure that was violated during the removal or installation of landing gear components.

Removing Landing Gear Components. Probably you heard about the mechanic who was trying to remove a nose landing gear actuator without having the aircraft jacked. On this particular model of aircraft, the nose gear actuating cylinder was acting as the landing gear downlock. The mechanic removed the hydraulic lines and then took the nut and washer off the mount bolt. The mechanic tried to take the bolt out that was connecting the actuator to the nose strut. It was extremely difficult to do so. The mechanic then took a large hammer and beat the bolt out of the eye bolt that was attached to the strut. As the bolt was forced out of the eye bolt, the nose gear collapsed.

Let's look at another example; but in this case the mechanic had just installed the landing gear control valve. After installing the control valve, the mechanic decided to perform an operational check. The mechanic jacked the aircraft and applied hydraulic and electrical power. The mechanic then raised the control lever in the cockpit to the UP position, but nothing happened. The mechanic looked in the wheel well (where the control valve was located) and noticed that the cannon plug on the control valve was left off. Without dropping hydraulic pressure, the mechanic went into the wheel well and started screwing the cannon plug onto the control valve. With hydraulic pressure, electrical power, and the landing gear lever still in the UP position, the landing gear retracted. Another thing wrong in this situation was that the mechanic was still in the wheel well when the gear retracted.

These are only two examples of what can happen when technical order procedures are not followed when removing and installing components in the landing gear system. To cover the removal and replacement of all the landing gear components in all the landing gear systems in the Air Force inventory is beyond the scope of this CDC. We encourage you to follow technical order procedure. The steps that follow are general information that can be applied to most aircraft.

(1) Assemble all the tools and equipment needed to remove the component.

(2) Determine whether the aircraft should be jacked. Some landing gear components do not need the aircraft

jacked in order to change them. The TO should indicate this.

(3) Depressurize the hydraulic system, and remove electrical power.

(4) Make sure that ground safety pins are installed.

(5) Disconnect the hydraulic lines and cap or plug lines. in some cases it may be necessary to tag the lines to indicate to what ports they should be installed.

(6) Remove any electrical connections, cannon plugs, quick disconnects or switches.

(7) Remove the mount bolts and the component.

Installing Landing Gear Components. Once the landing gear component is removed, if you have the replacement part, you can proceed to install the replacement part. The installation procedure is basically the reverse of removal. The only difference will be that the new O-ring seals should be installed during installation. After installation, the system should be operationally checked to insure proper system operation.

Exercises (621):

Read the following situations and determine what step was violated during the removal or installation of a landing gear component.

1. The mechanic had to stop because a special tool was not available.

2. Fluid was dripping down the mechanic's arm when removing the mount bolts.

3. Fluid sprayed out during the removal of the hydraulic lines.

4. The mechanic couldn't figure out which ports the hydraulic lines were supposed to go to during installation of a component.

5. The landing gear started leaking after installation.

6. After the first flight, a landing gear system malfunctioned after a component in the system was removed and installed.

622. Specify equipment and reasons for the procedures for performing an operational check of the landing gear.

Conditions Requiring Operational Check. One method of locating malfunctions in the landing gear system is to perform a gear operational check in which you retract and extend the gear.

There are, of course, several occasions when you should make an operational check. First, you should make an operational check during a periodic inspection of the landing gear system. Second, if you perform maintenance that might affect the landing gear linkage or adjustment (such as changing a shock strut), you should make an operational check to see whether or not you have everything connected and adjusted properly. Third, it may be necessary for you to make an operational check of the landing gear after a hard landing has been made that could damage the landing gear. You should closely inspect the gear and then make the operational check. Finally, the pilot, while flying the aircraft, may notice some malfunction in the operation of the landing gear system and request that an operational check of the gear be performed; then, of course you would check to locate the trouble.

Equipment. The first action taken when preparing to perform an operational check of the landing gear is to jack the aircraft (using proper jacks and jacking procedures were discussed earlier in this course). The aircraft must be raised high enough to allow the landing gear to safely clear the ground during all operational actions. Two units of powered AGE required to perform a landing gear operational check are:

(1) Hydraulic test stand,. This unit must have the capability of supplying the same volume output and pressure normally delivered by the engine-driven pump. For example, the hydraulic power requirements for the retraction of an aircraft landing gear may be 3,000 psi with a flow rate of 15 gpm.

(2) Electrical power unit. Electrical power is required for landing gear operation. The requirements vary from aircraft to aircraft; however, in most cases, the MD–3 or A/M32A–60 electrical power units can be used for a landing gear operational check.

Normal procedures. Procedures for an operational check of the landing gear are similar for most aircraft. The procedures given below are representative of a landing gear operational check.

(1) After the aircraft is properly jacked, remove the nose gear, main landing gear, and main landing gear inboard doors safety devices.

(2) Apply external electrical and hydraulic power (set the hydraulic power unit, as an example, to 3,000 psi with a flow rate of 15 gpm).

(3) After the hydraulic power unit has stabilized and the area has been checked for foreign objects, place the landing gear handle in the UP position. The nose and main landing gear should move smoothly to the UP and LOCKED position, before the inboard landing gear door closes. The landing gear control handle warning light should illuminate when the handle is moved to UP and should extinguish when the gear is UP and LOCKED. Also, the nose and

main landing gear position indicators should indicate barber pole while the gear is in transit and should indicate UP when the gear is UP and LOCKED.

(4) Place the landing gear control handle in the DOWN position. The nose and main gear should extend smoothly to the DOWN and LOCKED position. Once again, the landing gear control handle warning light should illuminate when the handle is moved to the DOWN position and should go out when the gear is down and locked.

(5) After the landing gear has been cycled a minimum of three times (and certified as in proper operating condition), the operational check is complete.

Emergency procedures. Most of today's aircraft have some means of lowering the gear in emergency. It could consist of just a cable the pilot pulls to release the gear uplocks, or some mechanical means of cranking the gear down. Some systems use an emergency hydraulic pump; others use pneumatic pressure. The procedures for lowering the gear using pneumatic pressure follow:

(1) Insure that the pneumatic system is serviced.

(2) Raise the gear until it is up and locked.

(3) Shut down hydraulic and electrical power.

(4) Place a container under the aircraft to catch any hydraulic fluid that might be poured overboard during extension.

(5) Next pull the emergency landing gear lever. The gear should lower smoothly and lock down. You can check for leakage of the pneumatic system at this time.

(6) Release the air holding the gear down. NOTE: Any time pneumatic pressure is used, the system must be bled of air before the aircraft is released for flight.

(7) Apply hydraulic and electrical power to the aircraft. CAUTION: Be sure to follow technical order procedures precisely at this point.

(8) Cycle the gear until the system is clear of air.

(9) At this time, secure the aircraft by removing all external power, installing all landing gear and landing gear door safety devices; then lower the aircraft and remove the jacks.

Exercises (622):

1. What are three conditions which require an operational check of the landing gear?

2. What aerospace ground equipment is required to perform an operational check of the landing gear?

3. The hydraulic test stand required to perform an operational check of the landing gear should be adjusted to what volume and pressure?

4. How high off the ground should the aircraft be jacked?

5. After lowering the gear in emergency using pneumatic pressure, what should be done before the aircraft is released?

6. What should the landing gear indicator show when the landing gear is in transit?

7. You have completed your operational check of the pneumatic emergency landing gear system and have applied hydraulic and electrical power to the aircraft. How long do you cycle the gear through its operation with hydraulic fluid?

8. During a normal operational check, when can the operational check be termed complete?

9. Why must a container be placed under the aircraft before the emergency landing gear system is activated to check gear extension?

10. During the emergency system operational check, one of the procedures is to release the air holding the gear down. When should this be done?

623. Tell why selected steps of servicing a shock strut are needed, and specify general operating principles relative to shock strut servicing.

Shock Strut Servicing. All shock struts are provided with an instruction plate that gives, in a condensed form, instructions relative to the filling of the strut with fluid and air. It is usually attached near the filler inlet and air valve assembly. If these instructions are not legible, you can also refer to the applicable aircraft TO for the servicing instructions. It is very important that you follow these instructions exactly. Failure to follow the instructions have resulted in collapsed nose gears and loss of steering.

Because of the various methods of servicing shock struts, we discuss only the most common method. It is called the hard strut method.

For efficient operation of shock struts, the proper fluid level and pneumatic pressure must be maintained. In order to check the fluid level, the shock strut must be deflated and be in the fully compressed position. Improper deflation of shock struts is highly dangerous; use approved precautions and procedures.

Remove all stands, jacks, and obstructions from under the aircraft. They could cause damage when the aircraft is

lowered. Make sure all personnel are clear of the aircraft. This is to prevent the possibility of injury in case of a sudden collapse of the strut.

Remove the air servicing valve cap and release the air pressure in the strut by slowly turning the air serviceability valve swivel nut counterclockwise approximately two turns. CAUTION: When loosening the swivel nut, insure that the body nut is held tight with a wrench. If it is loosened before the air pressure has been released, it could blow off and serious injury may result. The shock strut should compress as the air pressure is released.

When the strut is fully compressed, the air servicing valve assembly may be removed by breaking the safety wire and turning the body nut counterclockwise from the strut. This provides a hole for checking the fluid level in the strut and for adding hydraulic fluid when needed. Fill the strut with hydraulic fluid to the level of the air valve opening. The strut has the proper amount of fluid when you cannot get another drop in it, without it overflowing. Reinstall the air servicing valve, using a new O-ring seal. Torque the air servicing valve body nut from 100 to 110 inch-pounds. Lockwire the air servicing valve assembly to the strut, using the holes in the body nut.

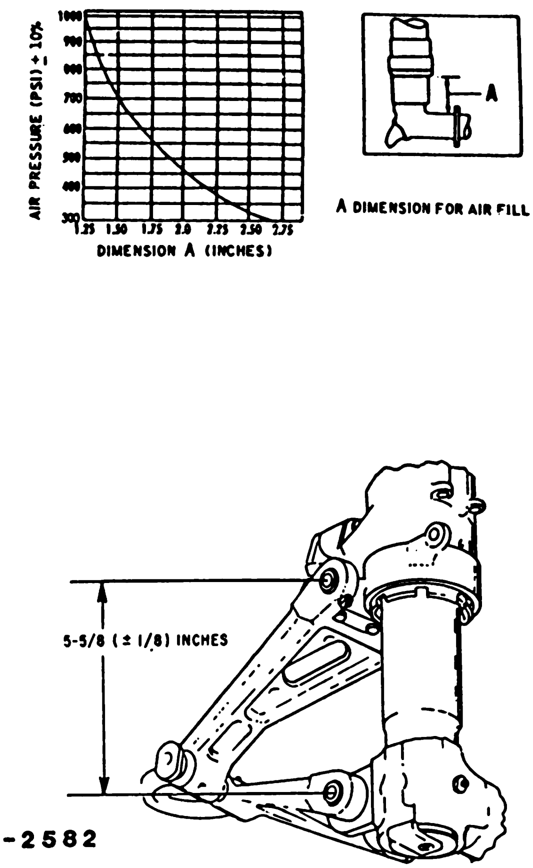
Attach a high-pressure air chuck and inflate the strut, using a regulated high-pressure source of nitrogen or dry compressed air. Under no circumstances should any type of bottle gas, other than nitrogen or compressed air, be used to inflate the shock struts. Nitrogen is preferred over compressed air. The amount a strut is inflated depends upon the specific aircraft strut being serviced. Figure 2-7 shows two ways of determining the amount a strut is inflated. In view B it shows a strut with the proper extension. It is measured from the center of the upper torque arm to the center of the lower torque arm. All you do is inflate the strut until you get this dimension. In view A you would have to use a strut inflation chart. The strut is measured as indicated at dimension "A." This measurement in inches is then located on the bottom of the inflation chart. For example, locate the measurement of 1.75 inches on the chart. Then from this point, trace an imaginary line vertically until it intersects the curved line. At this point of intersection, trace a second imaginary line horizontally to the left edge of the chart. The amount indicated at this point (550 psi) is the required pressure for that particular extension of the strut.

Whichever method you use to inflate the strut, the aircraft wings should be rocked while you service the strut with air (nitrogen). This helps eliminate any binding that might take place between the inner and outer cylinders. NOTE: Some aircraft must be placed on jacks with their struts completely extended in order to properly service them with air (nitrogen).

Once the strut is serviced to the specific amount, tighten the swivel nut on the air servicing valve to a recommended torque of 50 to 70 inch-pounds. Then remove the high-pressure air chuck and install the air servicing valve cap finger tight.

Proper servicing of shock struts cannot be overemphasized. If servicing instructions are not closely followed, serious damage could result. Listed below are just some of the malfunctions that could happen if the struts are not serviced properly.

A



B

CI 85-2582
10●

Figure 2–7. Shock strut servicing.

(1) Improper oil level in the strut chamber will decrease the shock absorbing capabilities of the strut and could cause the strut to bottom out during landing, which would damage the strut and/or wing structure.

(2) If the strut's chamber is underpressurized, the strut may not overcome normal O-ring friction during extention on takeoff. This condition could prevent the strut from fully extending, thus the scissors switch would not close the electrical circuit to retract the gear. It would also cause the strut to bottom during taxiing and landing operations.

(3) If the strut's chamber is overpressurized, with fluid or air, it could cause the scissors switch to actuate. This could cause the gear to retract on the ground if the gear handle is accidently moved from the DOWN position to the UP position. Also, if the nose strut is overpressurized, it could prevent normal steering, due to the fact that the centering cams would be engaged.

Exercises (623):

1. Where would information for servicing the shock strut be found?

2. In order to check the fluid level of the strut, what must be done?

3. Cite some safety precautions that must be accomplished before the air is let out of the strut.

4. Referring to figure 2-7, view A, how much air must be placed in the strut if the strut shows 2.0 inches of extension?

5. Why should the aircraft wings be rocked while servicing the strut with air or nitrogen?

6. How would you know the strut had the proper amount of hydraulic fluid in it during a servicing operation?

7. Why should all stands, jacks, and other obstructions be removed from under the aircraft prior to deflating the shock strut?

8. What would be the results if the shock strut was not filled with hydraulic fluid?

624. State specified actions concerned with how a strut assembly should be bench checked and repaired.

Shock Strut. Repair of shock strut is normally restricted to seal replacement and replacement of minor parts of the strut assembly. The following paragraphs provide general information on the disassembly, cleaning, inspection, parts replacement, and reassembly of a typical strut. Refer to figure 2-8.

Disassembly. Prior to beginning disassembly, ascertain that all air has been exhausted from the strut. Do not attempt to disassemble the inner and outer cylinder until all the air has been released from the strut. Disassembly of the strut prior to releasing all air pressure could lead to serious personnel injury or loss of life. After the air has been released, remove the complete air valve assembly by breaking the lockwire and unscrewing it from the strut. Next, disconnect the torque arms (scissors). Break the lockwire on the lower gland nut at the bottom of the outer cylinder. In some struts a bolt or lock pin is used to secure the gland nut. Now with the piston supported, unscrew the gland nut from the outer cylinder using the proper spanner wrench. With the gland nut off, withdraw the inner cylinder from the outer cylinder carefully so that the metering pin and orifice are not damaged. Note just as the lower bearing comes out of the outer cylinder the fluid in the strut will come gushing out. Have a drip pan available for catching the fluid. Pour the remaining hydraulic fluid from the inner cylinder into a suitable container, watching for small particles of rubber or metal that will indicate a wear condition within the strut. After the inner cylinder is empty of fluid place it in a clean work area, properly supported to insure that the machine surfaces will not be damaged. Remove the upper bearing and recoil valve (if so installed), follower, lower bearing, and other removeable parts in the order in which they are installed on the piston assembly.

Cleaning. Thoroughly clean all parts of the shock strut assembly, using specified cleaning solvent. Dry thoroughly with clean, dry, compressed air, paying particular attention to all recesses and internal passages. Use the cleaning solvent in a well-ventilated area.

Inspection. Perform a thorough visual inspection of the disassembled parts for serviceability. Inspect packing grooves and surrounding areas for scratches, burrs, nicks, or other roughness that might cut packings on installation or cause seal failure during strut operation. Inspect machine surfaces for mars, abrasions, gouges, grooves, scores, scratches, and corrosion. Bronze or brass bearing surfaces should be inspected for nicks, burrs, corrosion, or other damage. If any parts are suspected of having cracks, the part should be inspected utilizing one of the nondestructive methods of testing. All threaded parts should be checked for distorted or mutilated threads. Inspect chrome plated surfaces for blistering, flacking, wear, or other defects. All suspected defects should be tested to determine if the base metal has been exposed. For this, a copper sulphate solution should be applied to the suspected area. Wipe off the excess solution and inspect the part under a strong light. If the chrome plating has been penetrated, a copper coating will show on the iron metal where the chrome plating has been removed. Within the limits of practicability, check all holes for concentricity and taper, using micrometers or similar equipment. Inspect all ports, bores, and passages for cleanliness. The cylinder walls should be inspected for excessive wear, sharp edges, and corrosion.

Repair or replacement. Repair or replace all parts that show evidence of excessive wear, scoring, or corrosion. Replace parts that show wear beyond the dimensions specified in the applicable strut technical order. Each time the strut is disassembled, all preformed and special packings should be replaced, regardless of the fact that they may appear to be serviceable. Blend out minor scratches, nicks, and burrs from brass bearing surfaces with a fine tooth file.

CAUTION: Never use emery cloth or sandpaper because particles of grit will penetrate and remain in the bearing surface. The finished smoothness of the repaired area must be equivalent to or smoother than the finish of the surrounding area. Defects of the chrome-plated areas which have not penetrated the chrome-plating should be honed or polished to remove the sharp edges and prevent damage to the seals. A honing stone or crocus cloth may be utilized for this purpose. If the chrome plating has been penetrated, the

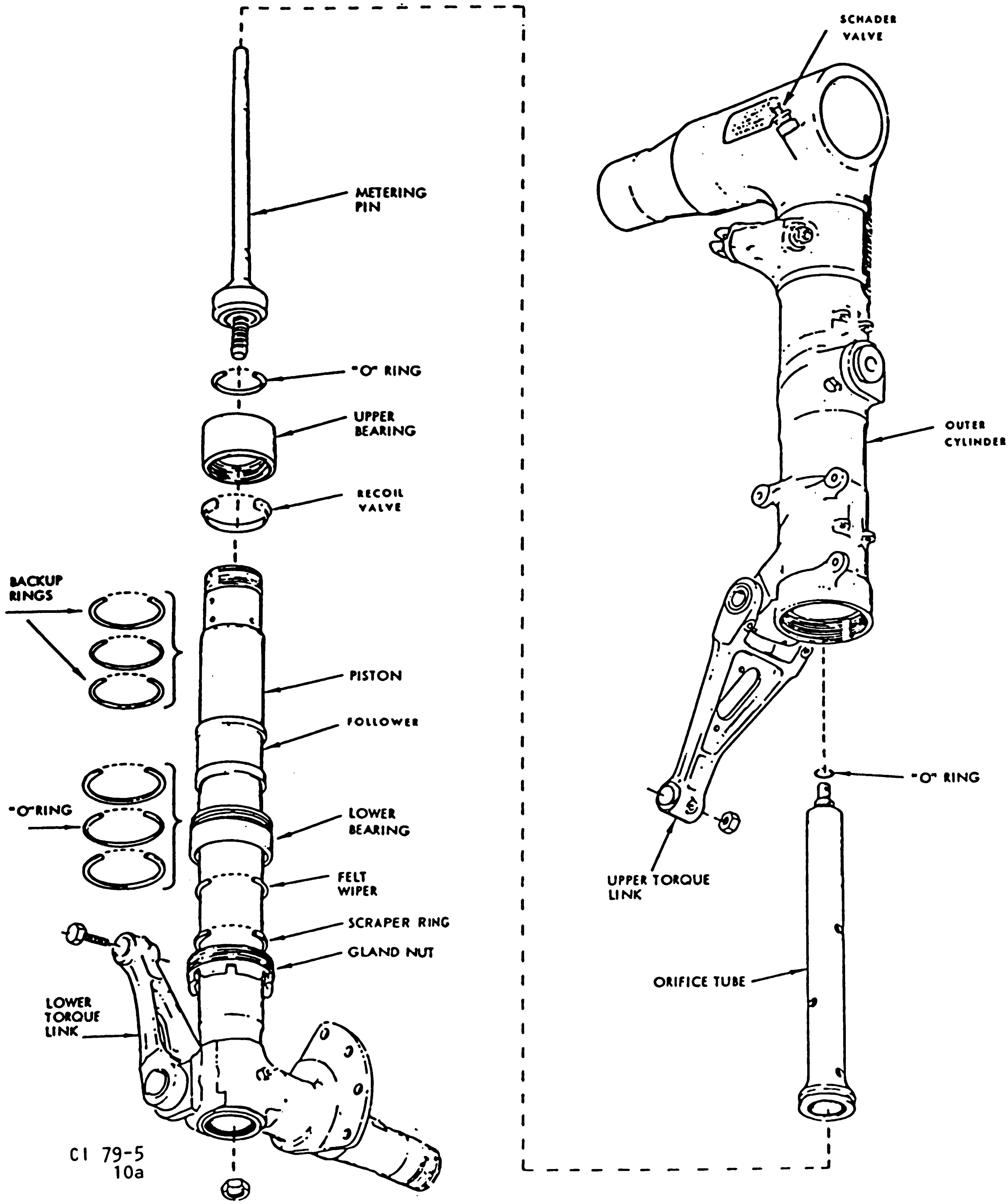


Figure 2–8. Landing gear strut.

strut should be replaced. (NOTE: Replacement of the inner cylinder only is not sanctioned.) If the inner cylinder is worn or damaged to the extent that it needs replacement, the complete strut will be removed as an assembly. By replacing the inner cylinder only, the integrity and safety of the strut is not guaranteed. Areas with damaged paint or other protective finishes must be restored to a serviceable condition. If this is not accomplished, it could cause corrosion to set in.

Reassembly. Reassemble the strut assembly in essentially the reverse order of disassembly. Exercise adequate precautions to insure that dirt, dust, grit, or other foreign matter does not enter the strut during assembly. Contamination of parts can cause definite failure and cannot be overemphasized. Lubricate surfaces of strut parts and seals with specified lubricant prior to reassembly. Slide the gland nut and scraper ring on the piston, insuring that the scraper ring is installed properly (flat surface of ring should face top of piston.) Install the lower bearing onto the inner cylinder with the felt wiper and seals. The follower will come next. If the strut is constructed with a recoil valve, insure that it is installed properly at the top of the piston. If the metering pin and orifice tube were removed during disassembly, install "O" rings and reinstall. With the installation of the upper bearing, the piston assembly is ready for installation. Insert the piston assembly into the outer cylinder carefully and tighten the gland nut to specified torque value. Secure the gland nut with screws or safety wire. Install the bolt which connects the upper and lower torque links and torque to specified limits.

Testing. If the strut is installed on the aircraft, service in accordance with specified aircraft technical order and check for leaks. If the strut is in the shop, the following general procedures should be used in order to check for leakage. With the strut fully compressed and in a vertical position, fill the strut with hydraulic fluid. (NOTE: Not all struts are serviced in this manner so be sure to consult the appropriate technical order.) Install the air valve on the strut and torque to 100 to 110 inch-pounds. Inflate the shock strut to the specified amount with dry air or nitrogen and allow the strut to extend. Use of only air pressure to pressurize the strut is prohibited, unless specifically authorized by TO. This prevents the possibility of introducing moisture into the air and oil chambers. Such moisture might bring on corrosion later. Also it is quite dangerous, because if the strut were to blow, it would be like a bomb going off, due to the large volume of air inside the strut.

Maintain the shock strut vertically for approximately 1 hour. During this time there should be no external leakage of fluids. Then place the shock strut in a horizontal position. The shock strut should not leak after a 1-hour interval. After the vertical and horizontal test, the shock strut assembly may be depressurized.

If the strut is to be sent to supply it must be properly prepared for storage. This includes servicing the strut with hydraulic preservative fluid Mil–H–6083 and covering all unpainted and exposed parts such as axles, joints, and brake flanges with a corrosion-preventative compound. In addition to corrosion treatment, the proper use of container (boxes, crates, etc.) is also important. The container for each strut protects it from damage and adverse weather. Always insure that the strut fits snugly into the cradles and mounting blocks of the container before closing the container.

Exercises (624):

1. A strut was removed from the aircraft because of a TCTO compliance. What precaution should you take to insure your safety prior to disassembly?

2. While disassembling the strut you notice that the gland nut has been damaged. What is the most logical reason that the nut was damaged?

3. Explain why the inner cylinder should be withdrawn from the outer cylinder carefully, after the gland nut is loosened?

4. While inspecting the fluid that was in the strut, you noticed small particles of metal. What would this indicate to you?

5. The bronze bearing between the upper and lower torque link has been struck by a rock during landing. What can be done to repair the damage?

6. Why isn't the inner cylinder replacement recommended?

7. During reassembly of the strut, how should the scrapper ring be installed?

8. List two reasons why air pressure only should *not* be used in testing a shock strut?

9. If the strut is going to be placed in supply, how should it be prepared?

625. Specify the general procedures to follow when removing and installing a component in the nosewheel steering system.

Once again because of the varied aircraft and the many types of nosewheel steering systems, we give you information only of a general nature on the removal and installation of nosewheel steering components. For specified information pertaining to a specific aircraft, be sure and obtain the appropriate aircraft technical order.

Removing Nosewheel Steering Components. The removal of most nosewheel steering system components is rather simple. To give you an idea of what must be done, the following steps are presented.

(1) Assemble all the tools and equipment needed to remove the component.

(2) Depressurize the hydraulic system and remove electrical power. Since many nosewheel steering systems have pressure trapped in them for shimmy damper action, all the pressure may not be depleted.

(3) Next, disconnect the hydraulic lines (fluid may squirt out because of the pressure trapped in the steering system for shimmy damper action). Cap or plug the lines to prevent contamination from entering.

(4) Remove any electrical connection cannon plugs, quick disconnects, or switches.

(5) If the components are mechanically controlled, such as the steering metering valves, the mechanical linkage must be disconnected.

(6) Remove the mount bolts and the component.

Installation of Nosewheel Steering Components. The installation procedure is basically the reverse of removal. Once again, though, you should replace the O-ring seals with new ones.

Exercises (625):

1. During removal of a steering control valve, fluid squirted out of the unit even though the system had been depressurized. Explain how this is possible.

2. If a cap or plug was not installed after removal of a steering component, what could possibly happen besides creating a mess?

3. You are given a work order to remove the steer damper on an aircraft. What would be the first step you should take besides getting the technical order?

626. Specify the reason for, and how to, perform specific steps of the operational check of the nosewheel steering system.

Nose Gear Wheel System Checks. Nose gear steering checks are required when a malfunction of the system is discovered or on routine inspections. Following the instructions in the maintenance manual, you usually check the throw of the nosewheel steering for the following conditions:

- Full right travel.
- Full left travel.
- Neutral position.

Occasionally, adjustment of the mechanical control linkages of the nose gear steering system is required to permit a specified degree turn of the nosewheel to the left or right of neutral.

On some aircraft, it may be necessary for you to jack the nose of the aircraft in order to check for centering. The centering cams in the nose strut will position the gear to the straight ahead or neutral position. Some aircraft require that the nose gear be placed on grease plates. This consists of two metal plates with grease between them. This way the nose gear can be positioned without placing too much of a bind on it.

A simplified operational checkout requires that the nose gear upper torque link and torque collar be separated. Usually mounted at the nose gear is a plate that can be used to determine the distance the nose gear is moved, whether on grease plates or with the torque links disconnected. We will discuss a typical nosewheel steering check.

Apply electrical and hydraulic power to the aircraft. Depress the control stick steering button. The nose gear should be in neutral 0°. Next move the rudder pedals full right, the nose gear torque collar should move to the maximum degree. Take your foot off the rudder pedal. The torque collar should return to NEUTRAL. Next move the nose gear full left. The nose gear steering collar should move to the maximum degree. Take your foot off the rudder pedal and the torque collar should return to NEUTRAL.

Reconnect the torque link and safety as required by applicable TO.

Exercises (626):

1. When the control stick steering button is depressed, what position should the nose gear be in?

2. Why do some checks require that a grease plate be used?

3. How can you determine how far the nose gear moves to the left or right?

4. Why is the aircraft jacked, in some cases, when checking the nosewheel steering?

627. Cite the reason for performing specific steps during removal, replacement, and bleeding of brake assemblies; and identify problems from situations pertaining to bleeding brakes.

Removing and Replacing Wheel Brake Assemblies. When removing and replacing brakes, follow the specific aircraft technical order. However, the following are some of the most common procedures used:

(1) Jack up the aircraft.

(2) Release the hydraulic and/or pneumatic pressure as necessary.

(3) Remove the main gear wheel.

(4) Disconnect the hydraulic and/or pneumatic lines at the brake assembly. Be sure to cap or plug the lines.

(5) Remove the brake-to-gear strut attachment bolts.

(6) Lift off the brake assembly.

Reinstall brake assembly by reversing removal procedures. Be careful not to damage any lines or threads. After installation, bleed brake system and perform operational check to check for leaks.

Brake System Bleeding. Air in a brake system may result from a lower reservoir fluid level, from external leaks, or from removing or replacing a unit. If there is air in a system, the brake pedal feels spongy when depressed instead of solid as it would be if the system has been properly serviced and bled. Two methods are used to bleed air from aircraft hydraulic brake systems: the gravity method and the pressure method.

Gravity method. The gravity method consists of pumping fluid through the system, using the master cylinder as a pump, as shown in figure 2-9. When using this method, connect a bleed hose to the bleeder port on the top of the brake unit. Place the free end of the hose in a clean receptacle containing hydraulic fluid. Depress the brake pedal slowly several times to pump the hydraulic fluid through the system into the receptacle. Close the bleeder port on each return stroke of the brake pedal to prevent fluid and air from being drawn back into the system from the receptacle. Continue this operation until no air bubbles appear and the spongy pedal action is eliminated. During this operation, be sure that plenty of hydraulic fluid is kept in the brake reservoir. If the reservoir is allowed to run dry, air is drawn into the system by the operation of the master cylinder.

Pressure method. The pressure method of brake bleeding consists of forcing fluid through the system with a brake bleeder, as shown in figure 2-10. When using this method,

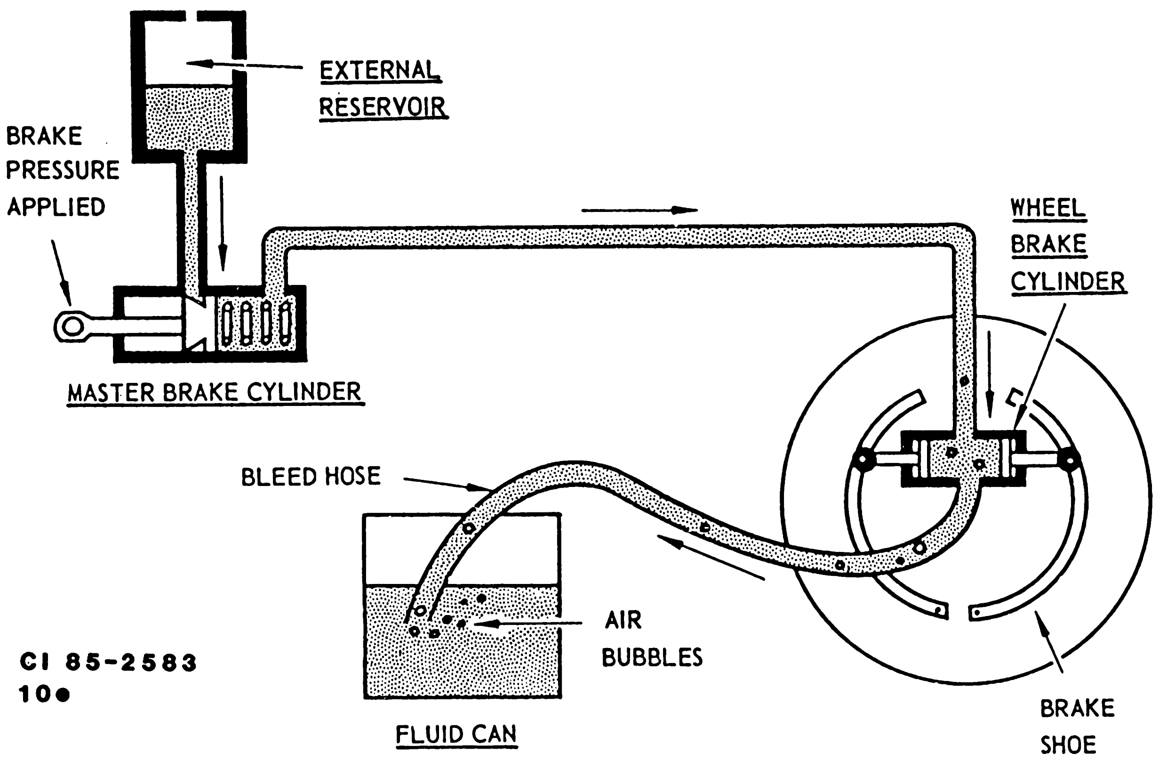


Figure 2–9. Bleeding brakes (gravity method).

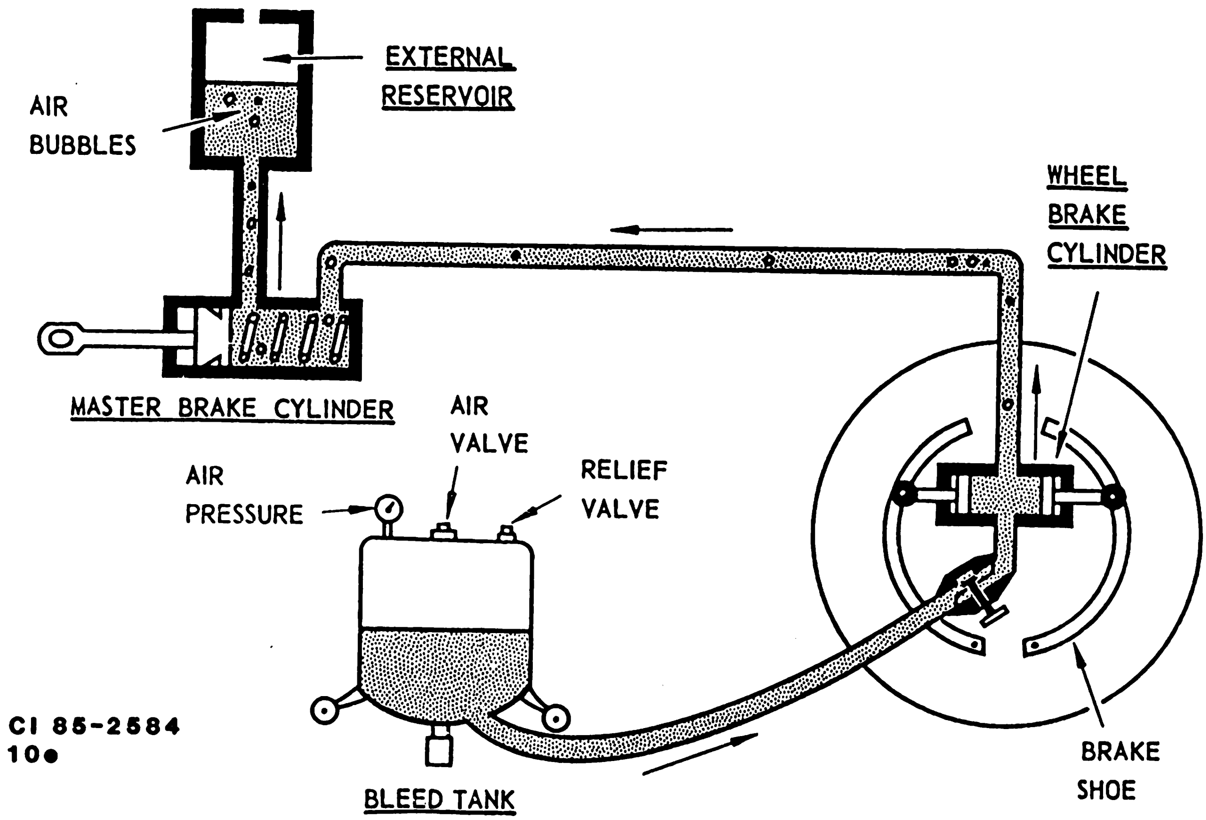


Figure 2–10. Bleeding brakes (pressure method).

first connect a bleed tank to the bleeder port on the brake unit. Air pressure in the tank removes the air by forcing the fluid through the system to the reservoir. Drain some fluid from the brake system reservoir to prevent it from overflowing. The amount of air pressure in the bleeder tank and the amount of fluid forced through the system varies with the aircraft concerned; therefore, you should always consult the brake servicing portion of the applicable −2 technical order before bleeding the brake system.

On aircraft with power brakes, the brake system is usually bled by the gravity method; however, there must be pressure in the hydraulic system, so that the brake system can receive fluid when the brake metering valve is operated.

Exercises (627):

1. The brakes on your aircraft are reported to be spongy after the installation of a new brake assembly. What is the most probable cause of this condition?

2. A subordinate has gravity bled the brake system to correct spongy brakes. Extreme sponginess develops after the subordinate had completed the procedure. What step did the mechanic omit which caused this condition?

3. While you are bleeding the brake system using the pressure method, the hydraulic reservoir overflows. What is the probable cause of this condition?

4. During the removal of the brake assembly, why should the lines be capped or plugged when removed?

5. When bleeding the brakes using the gravity method, the bleeder port is closed on each return stroke of the brake pedal. Why is this necessary?

6. When using the pressure method of bleeding brakes, where in the brake system is the bleed tank connected?

7. When using the gravity method of bleeding the brakes, how often must the brake bleeder port be opened and closed?

628. Arrange the proper sequence of the steps for performing an operational check of the wheel brake system.

Wheel Brake System Operational Check. The operational check of the brake system is conducted to assure satisfactory operation of the brake system after replacement of a component in the system, to check for leaks in the system, to isolate trouble if a malfunction is suspected in the system, and/or to meet routine inspection requirements.

At least two people should perform the operational check of the brake system. One operates the system and performs the necessary functions and checks in the cockpit. The other performs the necessary functions and checks at the landing gear wheels, service valves, and the external hydraulic test stand (if used).

The operational check is very similar on all aircraft except for specific items. The checkout requires the use of an electrical power source, hydraulic power source, and two hydraulic pressure gages. The two gages are installed in the bleed valves after cleaning the valves with solvent. Insure that the landing gear handle is down and antiskid switch is off. Connect electrical and hydraulic power to the aircraft. One person in the cockpit applies the brakes while the ground person checks for specified pressure (as an example 2700–3000 psi on the gages) and makes sure brake discs are applied. The brakes are then released; the pressure in the gages should decrease (as an example, to 50 psi or less) and the brake discs should be loose. Place the antiskid switch to ON and observe if the antiskid light goes out. Apply brake pressure and observe the pressure gages. Place antiskid switch OFF. The light should go out. Next, check the brake pedal binding with a spring scale for resistance when the pedal is depressed slightly. Then apply hard pressure to both brake pedals, observing pedal position and negative pedal fade. This completes the checkout procedures. The pressure gages and electrical and hydraulic power can be removed from the aircraft. In the event of malfunction during any brake check, refer to the applicable -2 TO.

Exercises (628):

1. Arrange in the correct sequence the steps for performing an operational check of the wheel brake system by placing a letter by each of the following steps:

   Step 1. ___ a. Connect electrical and hydraulic power.
   Step 2. ___ b. Place antiskid switch on—Light is out.
   Step 3. ___ c. Insure that landing gear handle is down and antiskid switch is off.
   Step 4. ___ d. Install gages in bleed valves.
   Step 5. ___ e. Release brakes and check pressure gages.
   Step 6. ___ f. Apply brakes and observe gages.
   Step 7. ___ g. Check for brake pedal binding.
   Step 8. ___ h. Place antiskid switch to off—Light is out.
   Step 9. ___ i. Apply hard pressure to both pedals and check for negative pedal fade.
   Step 10. ___ j. Disconnect power and gages from the aircraft.

629. Specify the operating principles that pertain to the bench check and repair procedures of hydraulic components.

Bench Check of Components. When a unit is taken from an aircraft, it usually ends up in the shop for a bench check. It can either go directly to the shop or it can go through the supply channels of the reparable processing center (RPC). As with any other job, there are set procedures for bench checking. In this section we discuss these procedures in detail, starting with the first steps and moving on until the unit is ready to be repaired.

You should know that the first thing to be done, in any job, is to locate the applicable TO. In Volume 1 we have discussed the procedures for finding the proper TOs. Not needing to repeat this, we can go directly on to the following steps.

Inspect for obvious damage. This action involves a general external inspection of the unit. You should check for any visible damage to the unit that could cause the malfunction or discrepancy. Such things as cracks in the body or stripped threads in the ports are considered obvious damage.

Just because you find obvious damage is no reason to stop without completing the bench check. After all, these defects could have been caused during removal of the unit. Therefore, you should always complete the job to see if there is anything more than obvious damage. It would be rather embarrassing if you should wait 2 or 3 days for a valve body and then found that some other parts of the unit were bad also.

Disassembly. Many TOs tell you to disassemble a unit by following the index numbers of the parts breakdown figure. Those that do not do this will list the complete procedures for disassembling the unit. Either way, lay out all parts in an orderly manner so that they can be put back together in the correct sequence.

More clues to the unit malfunction can be found during disassembly. You might, for example, find a poppet stuck open. Or you might discover that a slide has been scratched, causing excessive leakage at one port.

Cleaning. When the unit has been disassembled, clean all of its parts. How they are cleaned depends upon the construction of the unit. For instance, you should not use PD-680 solvent on a unit not compatible with petroleum base solvents. However, PD-680 is suitable for any unit that comes into contact with hydraulic fluid.

The parts of a unit are cleaned for several reasons. One is so that there will be no foreign matter left to contaminate the system when the unit is reassembled. Such foreign matter could clog an orifice or cause a poppet to stick. Also, clean parts assure more accurate inspection than dirty ones.

Inspection. After a unit has been disassembled and its parts cleaned, you should inspect the parts to insure their serviceability. Check for nicks and scratches that could cause a leak. Measure the tension of springs and check your

findings against the limits listed in the applicable TO. Insure that all slides properly seat in their sleeves and that they move freely.

During this inspection, you should list all parts that are bad or are doubtful. Use this list when you order parts to repair the unit.

Ordering Parts. Now that you have a list of parts needed to repair a unit, you will have to order them. Just as the overhaul time you spend is charged to the unit, so too are the parts you order for it charged to it.

Units brought to the shop for repair normally have a supply document number. This number is used for identification and control of repairable items. When you order parts for a unit, you identify the unit that the parts are to be charged to. Reference the unit by using its document number. Furthermore, each recoverable part you order for a unit has its own document number.

Shortly after you order these parts, supply can tell you whether or not you will receive them at once. Back order those not on hand in supply. Normally, not until all parts are received do you begin the repair of the item. This brings us to the repairing of an item.

Repair of Components. Unless circumstances prevent it, bench check and repair actions are normally taken at the same time. After you have bench checked the unit, you would logically begin to repair it. A circumstance that would prevent this is when all parts needed for repair are not available. In such a case you should put the unit with all its parts in an AWP (awaiting parts) storage bin.

Assuming all parts are available, we list the procedure for repair of a unit. Because we are repairing it immediately after completing the bench check, we can assume you already have the correct TO on hand.

Reassembly. The first step in repairing a unit is reassembling its parts. There are several precautions you must observe when you are doing this. To begin with, all O-ring seals and gaskets must be replaced. The sequence for reassembling a unit is usually the reverse of its disassembly. That is, the parts you took off last will probably go on first.

When you are reassembling a unit, remember to put parts back in the same position from which they were removed. As an example of this, think of yourself as working on a solenoid valve with two apparently identical parts. You must replace these and other items in their original position, because they may be mated to their retainers. You cannot change just the slide of a slide and sleeve assembly either, because they come in matched sets.

When you have reassembled the unit, you are ready to test it. Before you start your testing procedure, it is wise for you to go back over the steps in the applicable TO, just to make sure that nothing has been missed.

Test procedures. A unit that has been overhauled must be operationally checked. After all, just because you have changed a solenoid in a valve, doesn't mean that the valve will now operate properly. But you must make sure that it operates flawlessly before you send it back to supply as serviceable. Remember, you might be the one who has to put it on an aircraft, and then find out that it doesn't work correctly.

Exercises (629):

1. What does "inspect for obvious damage" indicate?

2. Explain why parts are cleaned during bench check.

3. If an item has matched parts, what should be done with them?

4. Why must a component that has been repaired be tested?

5. Why is it important to check each part of a component for serviceability?

6. When you order a part for a unit, what document number do you reference?

7. What circumstances would prevent you from repairing a unit when it is bench checked?

8. If all the parts needed to repair a unit were not available, what would you do with the unit?

630. Given hypothetical troubleshooting situations of a landing gear system, determine what could cause these malfunctions.

Landing Gear System Characteristics. Before we get into troubleshooting a landing gear system we should know some general characteristics of landing gear systems. First of all most landing gear systems have some type of warning indication to show if the gear is safe or unsafe. Secondly, most gear systems are designed to remain pressurized while the landing gear is down, and depressurized when the gear is up. The reason for this is that it insures that the gear will remain down and locked while on the ground and yet on long flights will save wear and tear on the system when the gear is up and locked. Also by being depressurized it prevents depleting system pressure or causing a fire if the aircraft is hit by enemy fire. Third, the landing gear must have some means of being locked in the up and/or down positions. This may be accomplished by overcenter locks,

springs, or locks built into the hydraulic actuating cylinders themselves. Fourth, the gear must have some type of sequencing, mechanical, hydraulic, or electrically. For example, you wouldn't want the door to close before the gear is retracted. In the schematic in foldouts 3 and 4, the doors (not shown) are mechanically attached to the gears, so any time the gears raise or lower the doors will also. In the schematics in foldouts 3 and 4, we have only included the electrical, hydraulic, and mechanical means of raising and lowering the gear. The indicating, warning, and touchdown circuits have not been included since these circuits will more than likely be troubleshot by other shops.

Troubleshooting the Landing Gear System. Now let's look at these specific malfunctions that you as a pneudraulic specialist might come across while troubleshooting a landing gear system:

- Landing gear will not retract.
- Landing gear will not extend (normally and in emergency).
- Landing gear will not extend or retract at specified time limits.

Failure of the gear to retract after takeoff could be caused by several items. Check your gages to insure that you have enough pressure. Check the electrical system by insuring that the circuit breakers are pushed in for the system involved. If the hydraulic pressure and electrical circuit breakers are normal, determine if one or all of the gears have malfunctioned. If all the gears have malfunctioned, by looking at the system schematic determine what items are common to each gear. Malfunction of only one gear could be a mechanical problem, a switch, or a hydraulic component applicable to only that gear. Let's assume that none of the gears came up when the landing gear selector valve was placed to the up position. Notice that the only item common to all the gears is the selector valve. In order to energize the selector valve to the "UP" position any one of the three switches on the gear will complete the circuit to the gear selector valve. It is very unlikely that all three switches have malfunctioned. But of course nothing is impossible. So, if the landing gear handle is positioned to raise the gear and none of the gears move, then it is a good possibility that the gear selector valve has malfunctioned. Now let's see what can happen if only one gear rises and the others stay down. Look again at foldout 3 and determine what components are installed in the gear-up circuit of that particular gear. Let's assume that the nose gear didn't come up when the selector valve was placed in the "UP" position. Since the other gear came up you can assume that the landing gear selector valve is good. You can also assume that the electrical and hydraulic systems are functioning properly. By tracing the fluid flow to the nose gear actuator you can see a two-way flow regulator, which could cause a blockage of fluid to the actuator. Also, since the down lock is built into the actuator it too could cause the problem. The fluid leaving the actuator must flow through a shuttle valve before it enters the selector valve. That valve, too, could have some internal damage that could block the fluid leaving the actuator. Some other items that could prevent the nose gear from retracting is a mechanical malfunction or a down lock that wasn't removed before flight.

If none of the landing gears extend when the gear selector valve is positioned to the DOWN position, look for a common component that could cause this to happen. (See foldout 4.) Notice that the landing gear selector switch, the circuit breaker, or the landing gear selector valve could cause this problem. A lack of hydraulic pressure could also cause this problem. Notice the check valve in the return line just below the landing gear selector valve. If this valve was installed the wrong way it too could prevent the gear from extending. The reason for this, of course, is that without a return flow the gear could not extend. Now let's assume that both the nose and the left gear extended when the handle was placed to the DOWN position, but the right gear didn't. Then, of course, you would look for something common to only that gear. This eliminates the selector valve circuit breaker and landing gear selector switch. Since the main landing gear is held in the up position by a disc brake, possibly the brake didn't release. In order for the brake to release, hydraulic pressure must be available. We know that hydraulic pressure is available to the other gear, but has it reached the brake itself? Also, the main gear is extended by a hydraulic motor; so, has pressure reached it? Let's not forget that any of the valves in the pressure or return lines to this gear could have internal damage of some kind that would prevent fluid flow through them. If the gear could not be extended normally, it will have to be extended manually by cranking it down. This system is fairly reliable, since the only part which could malfunction would be something mechanical, such as a broken cable, damaged screw jack, or possibly a gear box.

Another common malfunction with landing gears is that the gears do not retract or lower within specified time limits. As an example, let's say that the gear is supposed to completely rise within 19 seconds. If the gear takes 2 minutes, you can assume that something is wrong. One cause for this is that the flow (gpm) from the test stand or pump is not enough to satisfactorily raise the gear. If the flow from the pump or test stand is correct, determine if it is only one or all the gears. If it is all the gears then look for something common in the system. If it is only one gear, the problem is limited to just the components in that gear system. Let's assume that the right main gear does not retract within the specified time limit, but lowers at the proper time. Looking at foldout 4, you notice that the fluid flows from the landing gear selector valve through a flow regulator and controllable restrictor, both of which allow free flow to the hydraulic motor. The flow leaving the motor, though, must flow through a flow regulator, which regulates the flow back to return. This flow regulator in the landing gear down line could cause the gear to rise at a slower rate than specified. Remember, also, that just before the main gear reaches the up position, the front main gear strikes a lever which causes the controllable restrictor to restrict fluid to the hydraulic motor. If the controllable restrictor is adjusted improperly, it too could cause the gear to retract slower than normal. Since the gear lowered at the normal rate we can assume that the mechanical portion of the gear, such as jack screw and gear box, is operating properly.

Exercises (630):

Using foldouts 3 and 4 and hypothetical situations, troubleshoot the landing gear system.

1. The landing gear handle is placed to the UP position. All three gears rise until the two main gears are all the way up. At this point the selector valve is positioned to neutral but the nose gear is only partially up. What could be causing the malfunction?

2. The landing gear handle is at the DOWN position, but none of the gears extend. You check the landing gear circuit breaker and the availability of hydraulic pressure, both of which are all right. What could possibly cause this malfunction?

3. After the landing gear is placed in the UP position, the right main gear slams to the UP position while the left main gear rises smoothly. What is probably malfunctioning?

4. During emergency extension the nose and right main gears come down, but the left main gear does not. What possibly could cause this malfunction?

631. Specify how to bench check and repair a selector valve; then using a test procedure chart, explain the test being conducted and/or the test that should be accomplished.

Bench Check and Repair of Selector Valve. One of the items that periodically malfunctions in the landing gear system is the landing gear selector valve. The valve that we have selected to talk about is a four-way solenoid operated selector valve that may also be positioned manually by means of an override knob at each solenoid.

Let's start with the disassembly of the selector valve pictured in figure 2-11. Before disassembly begins, choose a clean working area. As parts are removed, place them in clean containers for protection against dust and dirt. Also note the manner in which the valve is safety-wired, so that it may be duplicated upon reassembly. Now, disassemble the selector valve according to numerical sequence of index numbers assigned to the exploded view, observing the following: Use a wooden dowel to press or tap shuttle and sleeve assemblies (21, 31) out of the body. These are matched assemblies, precision lapped at manufacture, so handle these items with extreme care. Also, do not intermix these components with like components or other assemblies. After disassembly, wash all nonelectrical metallic parts in cleaning solvent. Dry thoroughly with filtered, moisture-free compressed air. Wipe coil assemblies with clean, lint-free cloth moistened in cleaning solvent. Use stiff, nonmetallic bristle brush to loosen dirt, sludge, and other foreign matter from interior of body. Make certain that all ports and orifices are thoroughly cleaned. Then, under a strong light and preferably under magnification, inspect all parts for evidence of wear, corrosion, pitting, cracks, breaks, distortion, and stripped or crossed threads. Check the shuttle and sleeves for evidence of scoring or other damage to lapped mating surfaces. Check to see that the shuttle slides smoothly, with no evidence of binding or chattering within the sleeve. Do this by dipping the shuttle in hydraulic fluid; then carefully fit the shuttle into its respective sleeve. Inspect all packing grooves for mutilation, dirt, or any defect which might cause damage to or interfere with sealing. You should check the coils (16) for continuity and resistance, by using an ohmmeter. As an example, the resistance for the coils (16), shown in figure 2-11, should be approximately 48 to 53 ohms. Be sure to find the applicable resistance for any solenoid that you may be checking. Minor nicks, scratches, and imperfections may be removed by polishing with appropriate abrasive cloth. Do not attempt to polish the shuttle or sleeve assemblies. Remember, these items are machine parts and should be replaced if found damaged. If the coil is found defective it too should be replaced, as well as all O-rings and backups. Reassemble the valve in reverse order of index numbers assigned to exploded view. Moisten internal parts with hydraulic fluid prior to reassembly. (NOTE: On many selector valves an "X" is marked on matched parts to show the proper position of installation. Whenever assembling parts, especially matched parts, be sure and check for the "X" marks to insure that the parts are installed properly.)

After reassembly, the next thing is the testing of the unit. To perform the tests you must use a test stand capable of providing the desired pressure, flow, and electrical power source. In many of today's technical orders, a test procedure chart similar to the one shown in figure 2-12 is used for testing various units. It simplifies the procedure by showing the exact ports, valve positions, and pressure settings to use. By looking at figure 2-12, you can see various columns labeled with specific entries. As an example, let's look at test No. 1B. This is a "Proof Test." The valve will be in the neutral position, with the pressure port, cylinder port 1 and cylinder port 2, plugged. You will apply pressure to the return port at 1500 psi for 1 minute. Notice that the remarks column indicates there should be "No external leakage." As you can see, instead of searching through all the pages and between the lines to determine which position to place the unit or how much pressure to apply, everything is laid out for you. After testing, flush the unit with preservative oil and cap or plug all ports.

Exercises (631):

1. If a shuttle or sleeve is found damaged, how should they be repaired. Explain.

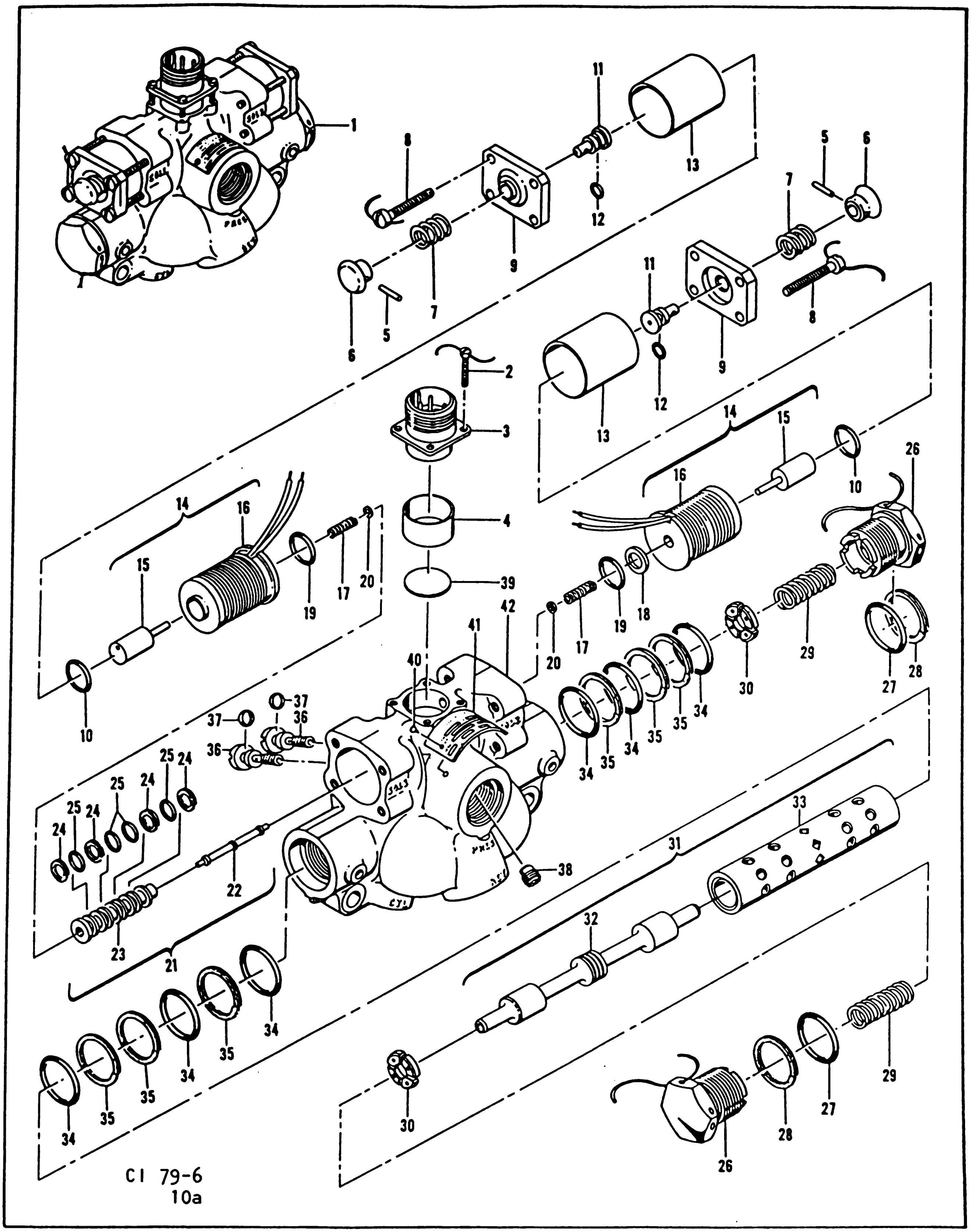


Figure 2–11. Selector valve breakdown.

TO TEST	NO.	VALVE POSITION	BLOCK PORTS	APPLY AT	PRESS. (PSIG)	TIME (MIN)	REMARKS
PROOF TEST and LOW PRESSURE OPERATION	1A	Neutral	PRESS., CYL 1 and CYL 2	RET	10	2	No external leakage.
	1B				1500	1	No external leakage. Repeat test.
CYCLING	2A	SOL. 1 energized	CYL 1 and CYL 2	PRESS.	4500	1	No external leakage. Valve shall show no tendency to stick or lag in moving to selected position or returning to neutral.
	2B	SOL. 2 energized					
	2C	See remarks			250	--	Cycle valve five times. No tendency to stick or lag in moving to selected position or returning to neutral.
TIMING and LEAKAGE TESTS	3A	SOL. 1 (see remarks)	CYL 1 and CYL 2 with pressure pick-ups	PRESS.	3000	5	Adjust pick-ups to actuate at 1500 PSI gage pressure. Energize specified solenoid. There shall be no audible sound from valve. Applicable pressure pick-up shall actuate with 0.25 seconds or less.
	3B	SOL. 2 (see remarks)					Leakage at RET port shall not exceed 10 CC per minute after a three-minute seating period. De-energize specified solenoid. There shall be no audible sound from valve. Within 0.1 second, applicable pressure pick-up shall actuate. Leakage from RET port shall not exceed five CC per minute after a three-minute seating period.
	3C	See remarks					Cycle valve five times by applying not more than 25 pounds force to manual override buttons. There shall be no signs of malfunction.
LOW VOLTAGE and CURRENT DRAIN	4A	SOL. 1 energized at 0-30 volts, DC	CYL 1 and CYL 2	PRESS.	3000	--	Slowly raise voltage from zero to 15 volts, DC. Valve shall shuttle. Increase voltage to 24 volts, DC. Current drain shall not exceed 0.8 ampere.
	4B	SOL. 2 energized at 0-30 volts, DC					
DIELECTRIC STRENGTH	5A	See remarks					Apply 1000 volts, AC, RMS, for one second between each solenoid and ground. There shall be no failure.

CI 79-7
10a

Figure 2–12. Selector valve test procedure.

2. How should the coils be tested for continuity?

3. Why are matched parts sometimes marked with an "X"?

4. Using the test procedure chart shown in figure 2-12, answer the following questions.

a. Under Test No. 3B, what is the allowable leakage from the return port, after the 3-minute seating period?

b. Test No. 4A requires 3000 psi. At which port will this pressure be applied?

c. Using Test No. 2A, what is the time limit for pressure to be applied?

Nosewheel Steering and Brake Systems

THE USE OF nosewheel steering and damping systems makes it possible to steer aircraft in confined areas without creating the usual disturbance or problems that stem from accelerating the engines or applying the brakes. The resultant longer life of engines and brake linings on aircraft using nose steering and damping systems justifies their use.

Pressure from the aircraft hydraulic system is used to turn the nosewheel either left or right, depending on the pilot's selection. Also the type of aircraft determines if the system is operated manually (mechanically) or electrically. In this chapter we talk about the operation and troubleshooting of a typical nosewheel steering system. Then we will select several components from the steering system which we will bench check and repair.

3-1. Operation and Troubleshooting

The nosewheel steering system which we have selected is typical of most cable-operated N/W/S systems. This system was selected because it has hydraulic components which can be bench checked and repaired. By talking about the operation, you have a better idea on how it should be troubleshot.

632. State specified constructional/operational features of a cable-operated nosewheel steering system.

Nosewheel Steering System Components. The landing gear steering system consists of a steering column, wheel, two steering cylinders, a steering control valve, and the necessary pulleys and cables to interconnect the steering cylinders, a steering control valve, and the necessary pulleys and cables to interconnect the steering components. Pressure for the steering system is applied by the utility hydraulic system through the nose gear down hydraulic lines. Figure 3-1 shows a diagram of the nosewheel steering system. Refer to this figure as we discuss the basic units of the system.

Steering wheel and column assembly. The steering wheel and column assembly consists of a steering wheel, a steering column, a sprocket, and the necessary brackets and hardware to secure the assembly to the aircraft. The steering column protrudes through the flight deck floor. At the end of the column is a sprocket to which a chain and cable assembly is attached.

Steering control valve. The steering control valve meters fluid to the steering cylinders. The control valve shaft is spring loaded to the neutral position to block off the pressure line. When this control valve shaft is displaced by the rocker arm assembly, fluid is directed to the steering cylinders. A filter element is installed in the pressure port of the control valve to prevent foreign matter from entering the valve.

Since the nose gear strut can be retracted and extended, swivel joints are installed on the pressure and return lines to the steering metering valves. If the swivel joints were not installed, then the lines could be damaged as the nose gear is raised and lowered. Also, notice that the pressure for the nosewheel steering system comes from the landing gear down line. Of course, when the landing gear is retracted, there is no need for nosewheel steering. When the gear is lowered, this will be the time that steering would be needed, and so fluid from the landing gear down line.

Nose gear steering cylinders. Two nose gear steering cylinders, located one on each side of the strut, supply power for turning the nose gear. The cylinders are double acting unbalanced. When the pressure port of the control valve is opened, fluid pressure is sent to the appropriate end of the cylinder for gear turning. The steering cylinder assemblies are connected by steering rods to the steering collar, which is part of the strut assembly.

Let's see what happens when the steering wheel is turned. At the beginning of a right turn, the cables with the black arrows become tight, and the cables with the white arrows become slack. This action changes the tension on the metering valve rocker arm, causing it to pivot. When the metering valve rocker arm pivots, the metering valve mechanism is positioned to send pressure to the steering actuators to rotate the nosewheel strut assembly. The cylinder barrels are designed to remain stationary, but the piston rods, attached to the steering collar, are movable. Also notice that pressure is applied to retract one actuator while the other extends. The steering collar is attached to the upper torque link of the strut. The lower torque link is attached to the strut piston. Both torque links are joined together to provide a mechanical linkage between the steering collar and the lower portion of the strut. As the steering cylinders move, notice that the steering collar also moves in a direction that tends to equalize the tension on the cables. This is commonly called a followup action and allows the metering valve to return to center, which stops fluid pressure to the steering actuators once the desired amount of travel has been acquired. The return fluid from the cylinders must blow through the compensator of the steering metering valve. The compensator keeps a certain amount of back pressure in the lines (approximately 90 psi) for shimmy damper action.

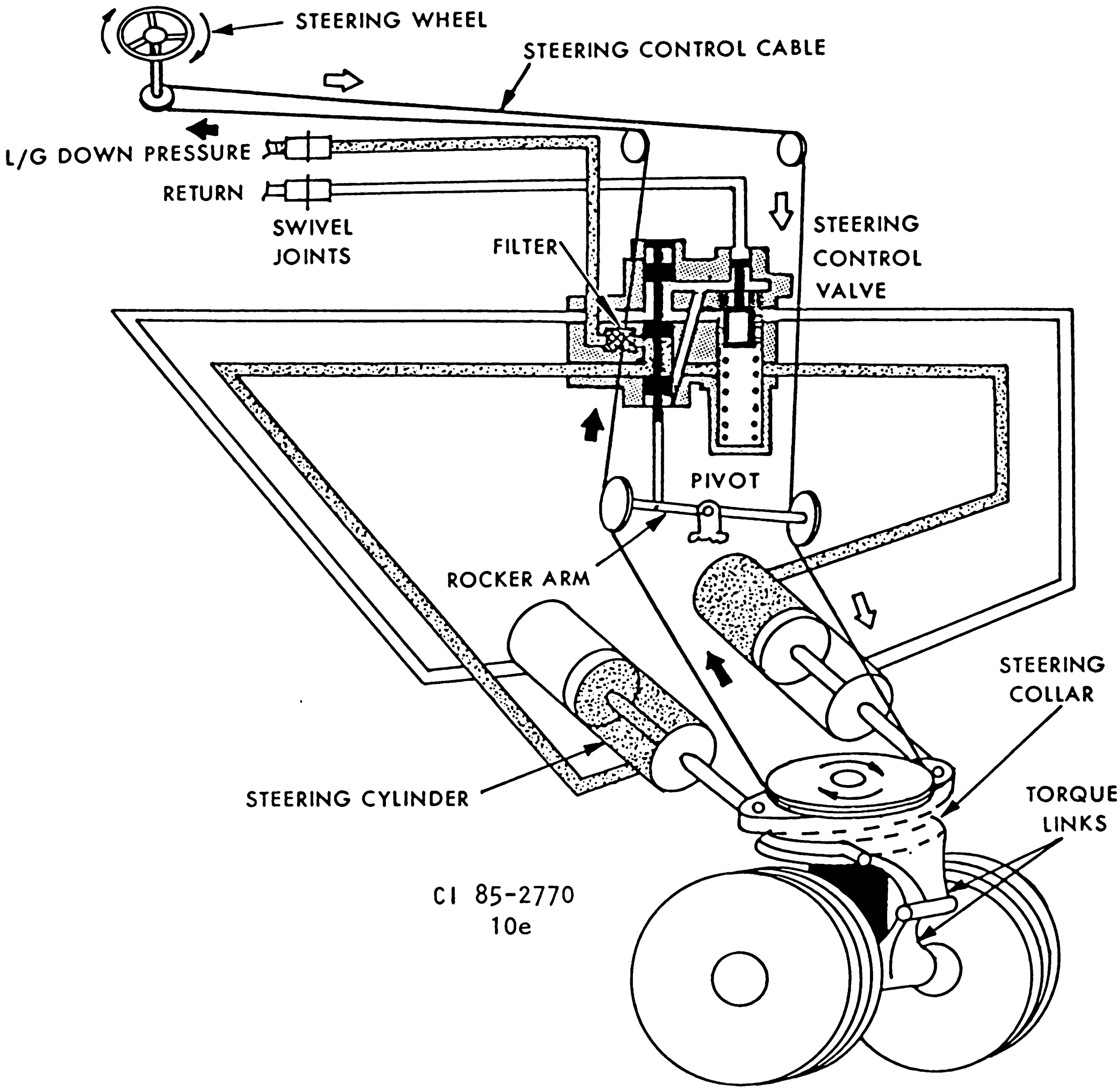


Figure 3–1. Nosewheel steering system.

During flight, or when the load is removed from the nose gear, centering cams within the strut position the wheels in the forward position for gear retraction.

Exercises (632):

1. What nosewheel steering unit is controlled by the steering column sprocket?

2. How is shimmy dampening achieved?

3. What type of steering cylinders are used in Figure 3-1?

4. How is the nose gear centered for retraction?

633. Given a hypothetical situation, and the schematic in Figure 3-1, solve nose gear steering system malfunction problems by stating applicable procedures or specific trouble.

Troubleshooting Steering System. Malfunctions in the nose gear steering system may occur in the mechanical (cable) or hydraulic part of the system. In either case, when a malfunction occurs, you must isolate the trouble and see that it is corrected.

Prior to troubleshooting the steering system, carefully inspect components for leakage, security, damage, and cleanliness. Some of the nosewheel steering problems normally encountered are listed below.

(1) Steering inoperative.
(2) Steering pulls left, right, or will not center.
(3) Nosewheel shimmy or erratic operation.

Take a look at figure 3-1 as we discuss each of these problems.

Steering inoperative. As you can see from Figure 3-1, the pressure for nosewheel steering comes from the landing gear down line. If for some reason the landing gear control valve has malfunctioned, there will be no pressure available for steering. Also notice that a filter is located in the pressure line of the steering control valve. If this filter became clogged it could cause the steering to be slow in operation or completely inoperative. Keeping the filter screens clean will decrease the chances of dirt entering the steering metering valve and causing a malfunction. Some other things that could cause the steering to be inoperative are the adjustment of the cables and the input linkage of the steering control valve.

Steering pulls left, right, or will not center. This could be caused by several items that you would never think possible. As an example, if the aircraft pulls to the left, it could be caused by low air pressure on the nose or main tires on the left side of the aircraft. Also, if a brake would not release, or maybe has trapped fluid, the brakes will pull the aircraft to the left. Rigging of the cables and input linkage to the steering control valve could also cause this problem.

Nosewheel shimmy or erratic in operation. If this malfunction occurs, you should check the steering control cables for security, proper rigging, and tension. Another thing that could cause nosewheel shimmy or erratic operation is the presence of air in the system. In this particular nosewheel steering system, a compensator (accumulator) is installed in the nosewheel steering control valve to trap a specified amount of fluid in the system to aid in shimmy dampening action. If a shimmy occurs, you should install a test gage in the system and check for this back pressure. If no pressure is found, then the control valve could be bad. Other things that could cause nosewheel shimmy are the tires. Check to see if the tires are out of round or improperly inflated. Also check the torque link bolts, wheel bearing steering collar and actuators for excessive wear or free play. Torque these items in accordance with proper technical order specifications. These are the most common troubles that are likely to occur on a cable-operated nosewheel steering system.

Exercises (633):

1. During system operation the steering cylinder mounting plate nut is found to be loose. What would indicate the loose nut?

2. The nose landing gear has excessive shimmy during takeoff and landing. Why should you install a gage in the system?

3. Why should the brakes and tires be checked if the aircraft pulls to the right?

3-2. Bench Check and Repair of Nose Wheel Steering Components

Most of the items in the nosewheel steering system are normally sent back to depot for repair. Items such as vane-type shimmy dampeners, servo control valves, and the like, are not normally repaired at field level. For this reason we have selected this system for discussion. Two of the items you, as pneudraulic mechanics, will come in contact with when working on the nosewheel steering systems are the nose steering control valve and the steering actuators. In this section we will first discuss the bench check and repair of the steering metering valve, then we will consider the steering actuator. Some of the steps have been deliberately left out for simplification, so be sure to use the proper technical order whenever working on these items.

634. Specify the procedures to use in bench checking and repairing a typical nosewheel control valve.

Bench Checking Steering Control Valve. When bench checking and repairing components, use the steps previously discussed in Volume 1. These consist of acquiring the special tools, disassembly, cleaning, inspection, repair or replacement, reassembly, and testing. The disassembly is the same order as the key index numbers assigned to the exploded view illustrated in figure 3-2, except that the locknut (12) must be loosened before removing bushing (11). Also be careful when removing the cap (20), because of the large spring (21). Clean all parts with P–D–680 cleaning solvent, and dry thoroughly with a clean, lint-free cloth or compressed air. Particular care should be taken when handling sleeve (17) and shaft (16). These items are mated parts which have been lapped to fit each other. In fact, the TO specifically states that you do not touch lapped surfaces unless your hands are clean and well oiled with MIL–H–5606. The natural salts and oils in your hands could cause a corrosive action to take place that would render these items unserviceable. After the valve has been disassembled, examine all parts for cracks and corrosion. Grooves and seats for packings and rings must be completely free of defects that might damage packings or rings. Inspect all polished surfaces for scoring, scratches

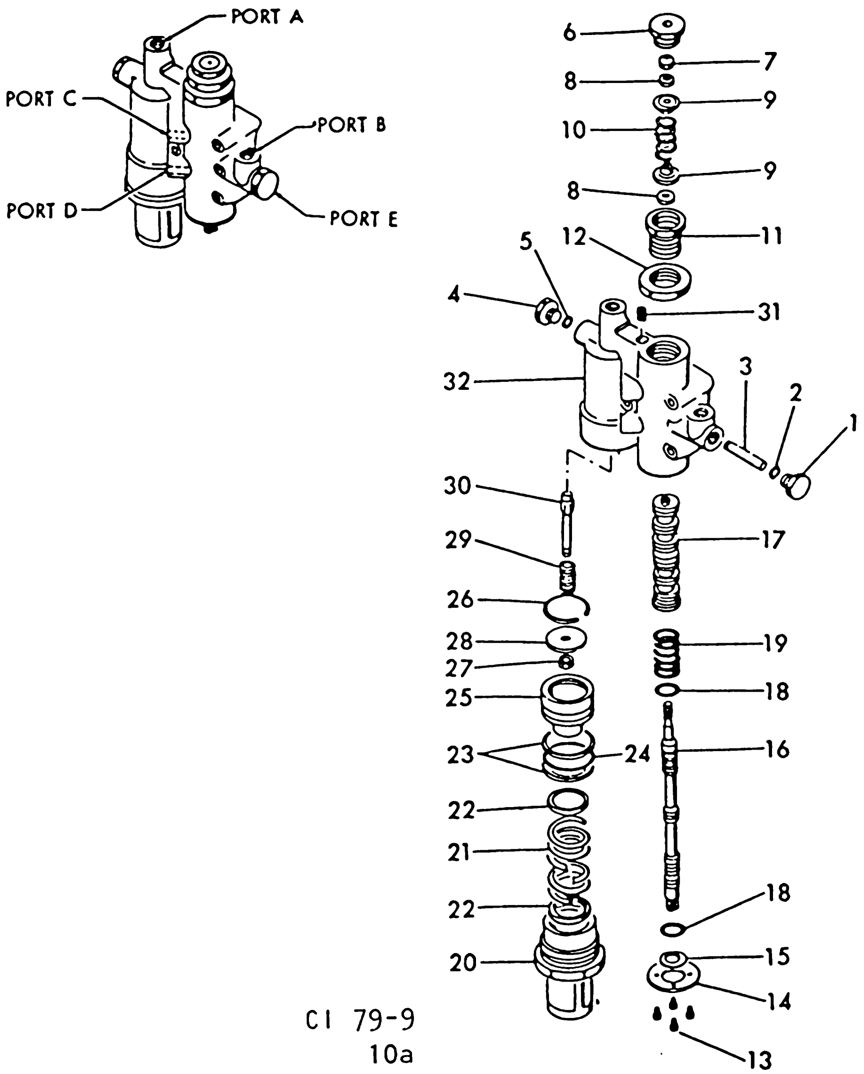


Figure 3–2. Nose steering metering valve breakdown.

and wear. Check all threads for burrs and damage. Remove minor nicks, scratches, and corrosion from parts, except lapped surfaces, by polishing with crocus cloth. Replace any part that cannot be repaired, as well as all packings. Shaft (16) and sleeve (17) are a matched set; if either part requires replacement, replace the assembly. Reassemble the components in reverse order of disassembly, except that the shaft (16) will have to be adjusted so that it is centered in port E, as viewed through the open port. After the unit has been reassembled, it is now ready for testing. Before we go through the various tests that should be performed, you should know the names and locations of the various ports. Notice that the upper left hand side of Figure 3-2 shows the complete valve with the ports lettered. These ports are:

- Port "A"—Return Port.
- Port "B"—Pressure Port.
- Port "C"—Cylinder Port.
- Port "D"—Cylinder Port nearest external portion of valve shaft.
- Port "E"—Filter Access Port.

The first test to be performed will be the proof pressure test. (CAUTION: During the proof pressure testing, do not actuate the valve while pressure is applied.) Plug ports A, C, D, and E. Then with the valve in neutral, apply proof pressure (4500 psi) to port B, and hold for 5 minutes. There should not be any damage or external leakage. Now, using the same procedure, test the unit in the depressed and extend positions. With the proof pressure completed, remove the plugs from A, C, and D. Leave the plug in port E. Place the valve in the neutral position once more and apply pressure (50 psi) to port D for 5 minutes. There should not be any leakage at port A, or around the seals on the shaft. With the valve in the same position, slowly increase the pressure until the compensator (relief valve) opens. This should be around 70 (± 20 psi). Now remove the plugs in port B, C, and E. Also disconnect the line to port D.

After these tests have been completed, check for shaft travel. Fully depress and extend the valve shaft and check for the proper travel as well as evidence of binding. Return the shaft to the neutral position. Now attach a pressure gage to port C and another gage to port D. With port A open, apply 3000 psi to port B. Fully extend the shaft and measure the pressures at ports C and D. The pressure measured at port C should be 3000 psi and the pressure at port D should not exceed 90 psi. When the shaft is released (returned to neutral), the pressure at ports C and D should be 70 ± 20 psi. Now fully depress the valve shaft. The pressures at ports C and D should be reversed.

Exercises (634):

Use figure 3-2 when answering the following questions.

1. What precaution should be taken when removing the cap (20) from the valve?

2. What should be done if the sleeve (17) is found damaged?

3. How should minor nicks be removed from nonlapped surfaces?

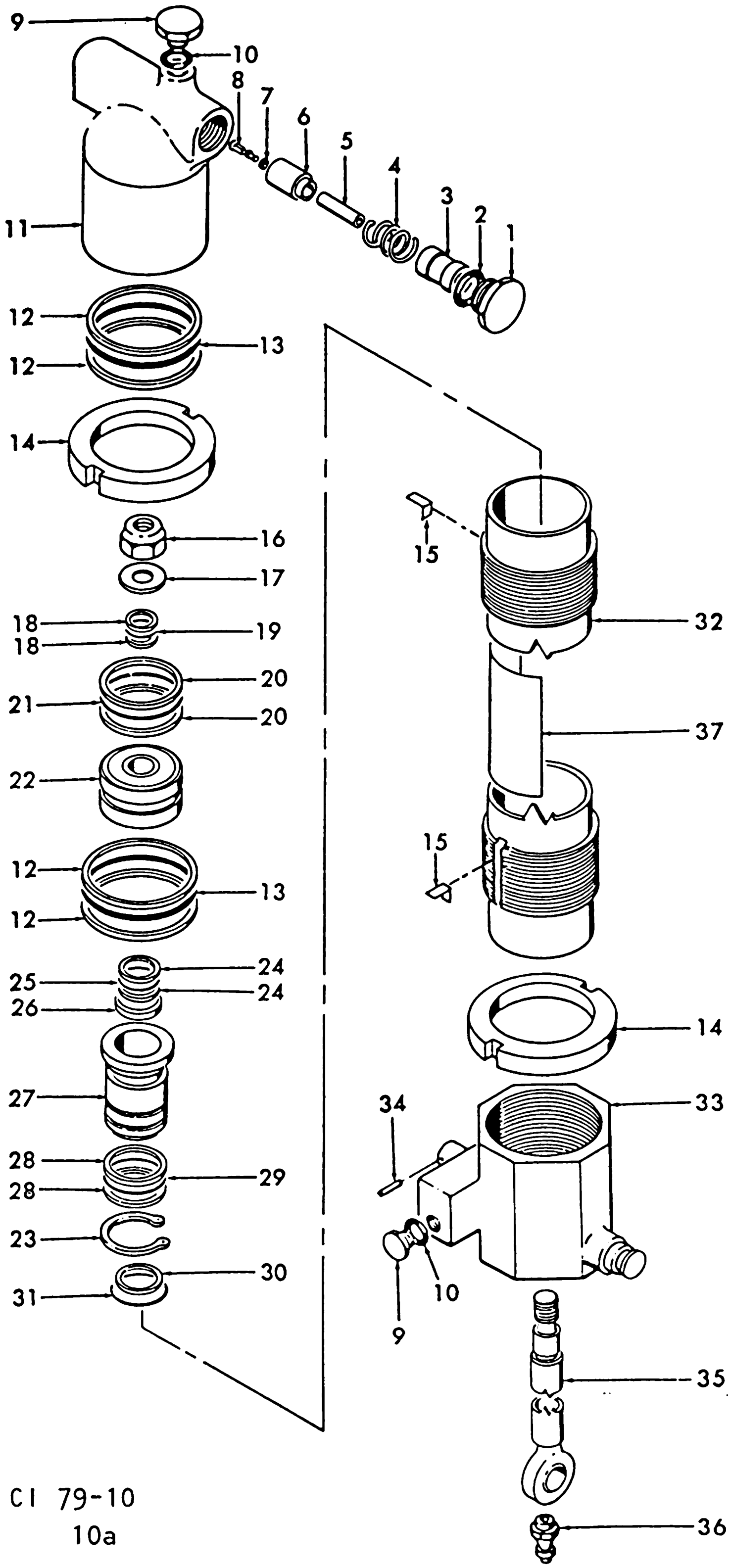
4. How can you tell if the shaft (16) is centered in the valve during reassembly?

5. With the valve in the neutral position, ports B, C, and E plugged, where should you check for fluid leakage—assuming 5 psi of pressure is applied to port D?

635. Specify the procedures to use when bench checking and repairing a nosewheel steering cylinder.

Bench Checking Steering Cylinder. The nosewheel steering cylinder is one of the items you can repair in the shop, especially if it is leaking (internally or externally). When the cylinder is to be repaired, choose a clean working area for disassembly. As parts are removed, place them in a clean container for protection against dirt and moisture. Disassemble the cylinder assembly in order of the key index numbers assigned to the exploded view shown in Figure 3-3. Before the lockring (14) can be loosened, the safety wire on the lock (15) must be cut. Then the lockring (14) must be loosened so the lock (15) can be removed. With the lock removed, the end cap can be unscrewed. (NOTE: Do not remove the nameplate (37) from the barrel. After disassembly, wash and clean all parts with cleaning solvent. After all dirt, sludge, and sediment have been removed, flush the parts with clean solvent. Dry with a clean, lint-free cloth, or use compressed air if available. Place all parts in a clean container until ready for reassembly. Do not clean packings, back-up rings or retainer rings removed during disassembly as these items should be replaced at each overhaul. Inspect the various parts.

Check the chrome-plated surface of rod assembly (35) for scoring and scratches. Reject the part if the plated surface is penetrated. Check the weld points where fittings and ends join the rod, for visible cracks. Check the bushing (27) for wear. Inspect the seating surfaces of seals to see that they are not nicked or damaged. Inspect the barrel (32) and cap (11) for scoring scratches. Ports and packing grooves must be clean and unobstructed. Replace all parts which are defective or which cannot be repaired to meet technical order specifications. Scratches and score marks no deeper than 0.0025 inches in polished surfaces, or scratches in chrome-plated surfaces which do not penetrate the plating, may be polished out with crocus cloth. Lubricate all packings with the specified lubricant; then reassemble the



1. PLUG AND BLEEDER
2. GASKET
3. RETAINER
4. SPRING
5. ELEMENT
6. VALVE
7. NUT
8. RETAINER
9. PLUG AND BLEEDER
10. GASKET
11. CAP
12. RING
13. PACKING
14. RING
15. LOCK
16. NUT
17. WASHER
18. RING
19. PACKING
20. RING
21. PACKING
22. PISTON
23. RING
24. RING
25. PACKING
26. FELT
27. BUSHING
28. RING
29. PACKING
30. SCRAPER
31. RING
32. BARREL
33. TRUNNION
34. PIN
35. ROD ASSY
36. FITTING
37. NAMEPLATE

Figure 3–3. Nose steering actutaor breakdown.

parts in the reverse of disassembly. After reassembly, you are ready for testing the unit. Connect the cylinder's retraction port on a hydraulic pressure source, as shown in figure 3-4. With the piston fully retracted and the extension port open, apply 4500 psi pressure to the retraction port and hold for 10 minutes. There should be no damage or internal or external leakage. Connect the cylinder assembly's extension port to a hydraulic pressure source with the piston fully extended and the retraction port open to atmosphere, apply 4500 psi pressure to the extension port, and hold for 5 minutes. Again, make sure there is no damage, internal or external leakage. Now set the actuator so that pressure can be applied alternately from the extend to the retract port. Using 3000 psi pressure, cycle the cylinder assembly five complete cycles. Operation should be smooth with no sticking or binding. After the pressure check, retract the piston fully and measure the distance between the centerline of the trunnion and the centerline of the rod end bearing. This dimension should not exceed specified technical order limits. If the measurement falls outside these limits, loosen the lockring one turn and adjust the cap on the barrel either way, as required. (NOTE: Insure that the lockslot in the trunnion (33, fig. 3-3) is lined up with the lockslot in the barrel (32) so the lock (15) can be positioned properly.) Now extend the piston fully and measure the distance between the centerline of the rod end bearing. This dimension should be as specified in the technical order. If the measurements fall outside specified limits, check the piston, rod, cap, and trunnion for correct assembly and internal obstructions. If the cylinder assembly does not meet the requirements of any of the above tests, disassemble the cylinder, reinspect the components, replace defective components, as well as those suspected as the cause of malfunctions, and reassemble. Then repeat all tests. After successful completion of the test, flush the cylinder assembly with MIL–H–6083 preservative. Then check the lockrings to insure that they are tight, safety the lockrings to the locks, and plug the ports for storage.

Exercises (635):

1. Prior to unscrewing the end cap from the cylinder barrel, why should the lockring be loosened?

2. Why should the weld joints be inspected?

3. While inspecting a polished area of the cylinder, you find a scratch 0.0017 inches deep. What can or should be done to correct this malfunction?

4. If the retracted length of the cylinder is not within limits, what can be done to bring it within specified technical order limits?

5. What precaution should be observed when installing the lock (15) in the cylinder?

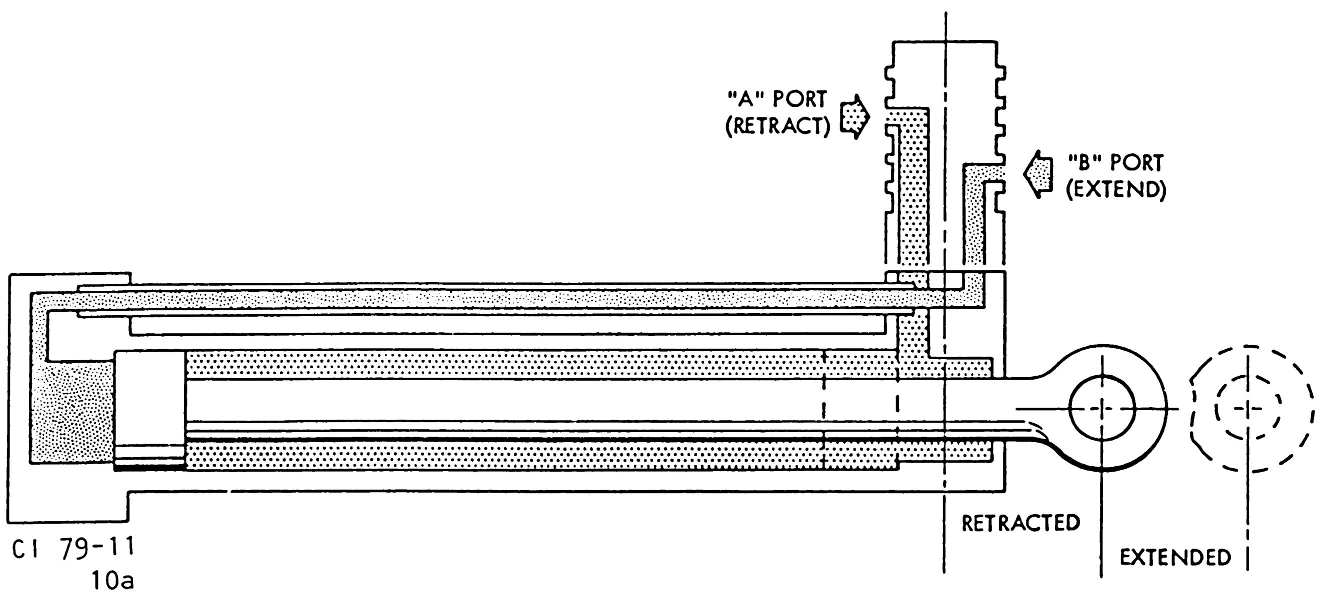


Figure 3–4. Testing steering actuator.

6. What is the time limit as specified in the objective for applying 4500 psi to the extension port?

7. List three things that should be done to the cylinder after completion of all tests.

NOTE: Brake systems are designed to retard or stop aircraft motion on the ground and to aid in controlling the direction of the aircraft while taxiing. Provisions exist for applying either one or both brakes and for varying the braking action by the amount of movement or force exerted on the brake pedal. Most modern aircraft have an antiskid system integrated with the wheel brake system to allow maximum braking, resulting in a short landing roll and skid free control until the aircraft comes to a stop. Some aircraft brake systems also incorporate an antispin feature which is designed to apply pressure to the brake assemblies during the landing gear retraction cycle.

3-3. Troubleshooting Brake System

A large portion of your job as a pneudraulic specialist is directed toward troubleshooting and repairing brake systems and components. In fact many shops have a separate section just for the bench check and repair of brake assemblies.

636. Given hypothetical situations relating to the brake system, analyze the situation to determine the problem.

Despite the differences among the several landing gear arrangements, all aircraft brake systems fall into three main types: (1) independent, (2) integral, and (3) slave brake systems. The type of brake system used is determined by the size and weight of the aircraft.

A common trouble encountered with brakes is air getting into the system. Air can be compressed; therefore, braking action will not be positive, and the brake pedal will have a spongy feel and a long stroke. Air can get into the system whenever a unit is disconnected or when a leak develops in the system. It may also be introduced in the other system by a low supply of fluid in the reservoir. Regardless of how the air enters the system, you must remove it by bleeding the system.

Another common trouble in the brake system is dragging brakes. When you encounter this writeup, first check the clearance of the brake lining. Adjust them for proper clearance, if necessary. When adjusting does not solve the problem, check the return (back) pressure with a gage. Among the things which can cause excessive back pressure, and thus keep the brakes applied, are these: (1) brake control valve(s) out of adjustment; (2) restricted return flow such as a clogged return filter; or (3) high reservoir pressure. First, check out each of these items to eliminate it as the cause of the problem. If none of this helps, you may have to disassemble the brake assembly and check for binding and warped components. By refering to the TOs covering brake assemblies, you can find the specific components of your brake to check.

Still another problem involving brakes is what is called a hot brake. Brakes used for maximum stopping, such as a rejected takeoff or brakes dragging over a long distance, become very hot. If a brake assembly has become overheated because of a rejected takeoff, the assembly should be inspected closely for heat damage, worn linkage, and cracks.

After a hot brake has cooled down, you must check to determine whether the condition was caused (1) by insufficient clearance or (2) by restricted return flow. (NOTE: It is difficult for you to tell if insufficient clearance has caused the condition by just checking the clearance itself.) Why? Because the brake lining will usually have worn enough so that you cannot tell for sure whether the clearance was too small previously. Thus, you must check the brake assembly for proper release and the maximum return pressure allowed. If the clearance has been proper previously, you should find some restriction or a higher than normal return pressure on the brake line with the brakes released.

Now let's look at some specific examples of malfunctions that may occur in a system (see foldout 8). We will break the system down into three separate sections so that it will be easier to troubleshoot. These sections are normal brakes, emergency brakes, and antiskid. We'll start first with normal brakes.

Normal brakes. One of the common malfunctions that you may encounter is that the aircraft pulls to one side when brakes are applied. This can be caused by several items: (1) air in the brake system; (2) a dragging brake or power brake control valve improperly rigged; or (3) internal leakage in the antiskid valve, shuttle valve, or power brake control valve.

Emergency brake system. One of the common problems in this system is that the correct amount of emergency brake application is not available. In other words the accumulator has not retained enough fluid under pressure to actuate the brakes. This problem can be caused by the accumulator incorrectly serviced with air or nitrogen or by the inline relief valve leaking internally. Some other causes are an excessive amount of air in the system and an external leakage in the emergency system.

Antiskid system. One common problem associated with the antiskid is that the antiskid system is inoperative. You can see from foldout 8 that in order for the antiskid system to operate, the antiskid switch must be in the ON position and the landing gear handle must be down. Check these two items as well as the circuit breakers associated with the antiskid circuits. Some other possibilities are that the antiskid control box or antiskid control valve is malfunctioning. Also, remember that the antiskid system is not operational during emergency operation. Make sure that you are in the normal breaking mode when operating the antiskid system.

Exercises (636):

Use foldout 8 to aid you when answering the following questions.

1. While landing, the pilot notices that the aircraft pulls to one side when the brake pedal is applied. After checking for internal leakage, you bleed the brakes, but the aircraft continues to pull to one side when brakes are applied. What could be causing the trouble?

2. A check of the emergency system reveals that the brakes would not hold when you press the brake pedal four times. The brakes are bled and the accumulator serviced, but the trouble still exists. What can be causing the trouble?

3. The pilot reports that the brakes are completely inoperative, when normal brake system is used and antiskid on. How can you quickly check to see if the problem is caused by the antiskid system?

3-4. Bench Check and Repair of Brake System Components

Think back as far as you can about the types of components that you have bench checked and repaired in the brake system. Some of the common components that may come to mind are power brake control valves, antiskid valves, and brake assemblies themselves. Now think about how many times you have bench checked and repaired a power brake control or antiskid valve. Very seldom do these two components malfunction, at least not enough to require a discussion on the bench check and repair of them in this section. Besides, these components require special test equipment that normally would not be found in an average pneudraulic shop. One of the items, though, that you will more than likely bench check and repair is the brake assembly itself. And since the multiple disc brake is used on many of the more advanced aircraft, it is the ideal brake to discuss. Along with the brake assembly you will quite often find a filter assembly, located somewhere in the system. For this reason we will also discuss the bench check and repair of a filter assembly.

637. Specify the procedures to follow during the bench check and repair of a multiple disc-type brake assembly.

Bench Check and Repair of Brake Assemblies. Brake assemblies are manufactured from magnesium, aluminum, and steel. The manufacturer surface treats these assemblies to provide a corrosion-resistant surface. However, this surface is easily scratched, creating a potential corrosion area. Therefore, all aircraft brake units must be thoroughly cleaned and inspected whenever work is done on them. After a brake is disassembled, clean the brake parts with a fiber brush or spray, using cleaning solvent, Specification PD–680. Do not use wire brushes or steelwool on aluminum or magnesium parts. Also avoid oversoaking of brake parts as this will cause lifting of the paint on the brake. After cleaning the brake, inspect it. Refer to figure 3-5 as we describe the various components to inspect. Visually inspect the brake housing for cracks, nicks, worn mounting holes, stripped threads, and corrosion. Inspect the discs for minimum thickness and warpage severe enough to create a drag. This can be determined by checking the discs on a surface plate. Check the drive slots for excessive wear or battering. Dimensions for drive key slots are given in the applicable TO. Visually inspect discs for cracks extending through the brake disc. Cracks are usually found at edges of keyways and/or expansion slots. Figure 3-6 shows examples of heat checks and cracks. A and C are heat checks, B and D are cracks. Any single crack that extends through the thickness of the brake disc will be reason for replacement. Surface cracks and/or heat checks are normal and should not be considered cause for replacement. The wear pads on the backing plate and pressure plate (shown in fig. 3-5) should be checked for wear. These pads are held in place by rivets. The rivets should be checked for cracks and security. Now refer to Figure 3-7 as we discuss the inspection of components within the brake housing. The grip and tube assembly should be checked for damage and gripping force. Do not disassemble the grip and tube assembly because they are mated parts. If they are to be replaced, replace them as a unit. The return springs should be checked for specified amount of force required to compress them. The piston should be checked for cracks and damage, especially around the area of the O-ring seal.

Brakes with minor defects should be reworked to relieve all sharp corners or indentation which might result in a concentration of stresses. Rework the piston to remove minor dents, nicks, burrs, and scratches. Grind brake discs as necessary to restore them to a serviceable condition, keeping within the tolerances outlined in the applicable manuals. Rotating and stationary discs that are found to be warped can be straightened by using a straightening tool. The tool is simply a mechanical or hydraulic press that compresses the discs like a sandwich, until they are within prescribed tolerances. If wear pads are worn, they should be replaced. When installing wear pads the rivet must be flush or below the surface of the wear pad. Also, only one crack is allowed on the rivets and it should not extend into the shank. After the inspection and repair of the brake components, lubricate the housing cylinder walls and new O-ring seals with the specified lubricant. Also lubricate bolt threads and bearing surfaces of bolt heads with antiseize compound. Reassemble the brake, paying particular attention to the assembly of the self-adjusting mechanism (grip tube, grip spring guide, and return spring). If this mechanism is not assembled properly it can cause the brake to drag.

Once the brake has been reassembled, it should be tested. Connect the brake assembly to a hydraulic pressure source. Then apply hydraulic pressure of approximately 3000 psi and hold for 2 minutes. Apply and release the brakes at least

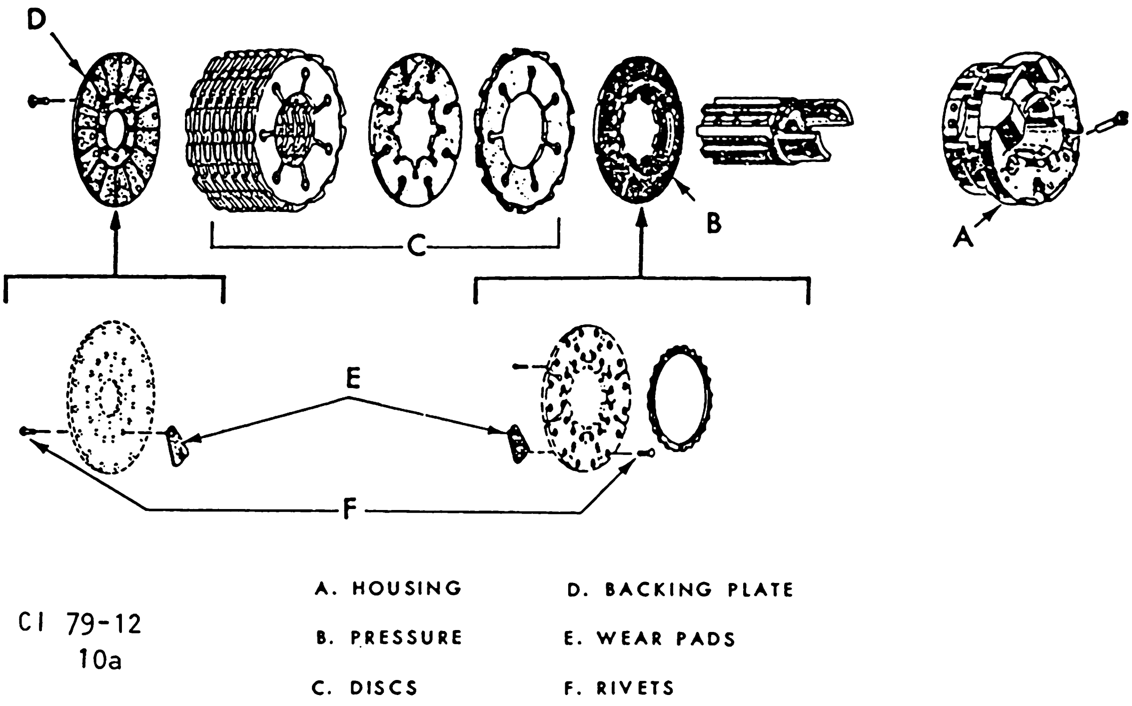


Figure 3–5. Multiple disc brake (breakdown).

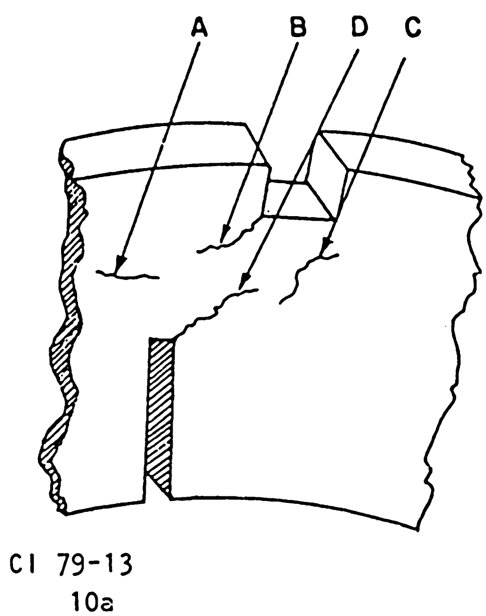


Figure 3–6. Heat checks and cracks.

ten times while checking for leakage. Now apply the brakes once more; then reduce the pressure to approximately 75 psi. With only 75 psi (which would simulate return line back pressure) check for the minimum (OFF) clearance. Reduce the pressure to 5 psi and check for static leakage for two minutes. After testing the brake assembly, disconnect it from the test set-up, drain it, and cap the open ports.

Exercises (637):

1. What could be the results if a brake is allowed to soak in the cleaning solvent for a long period of time?

2. List at least four items to check for when inspecting the discs.

3. What two items in the multiple brake just discussed should be checked for specified force?

4. What components of this brake assembly are matched parts and should never be interchanged?

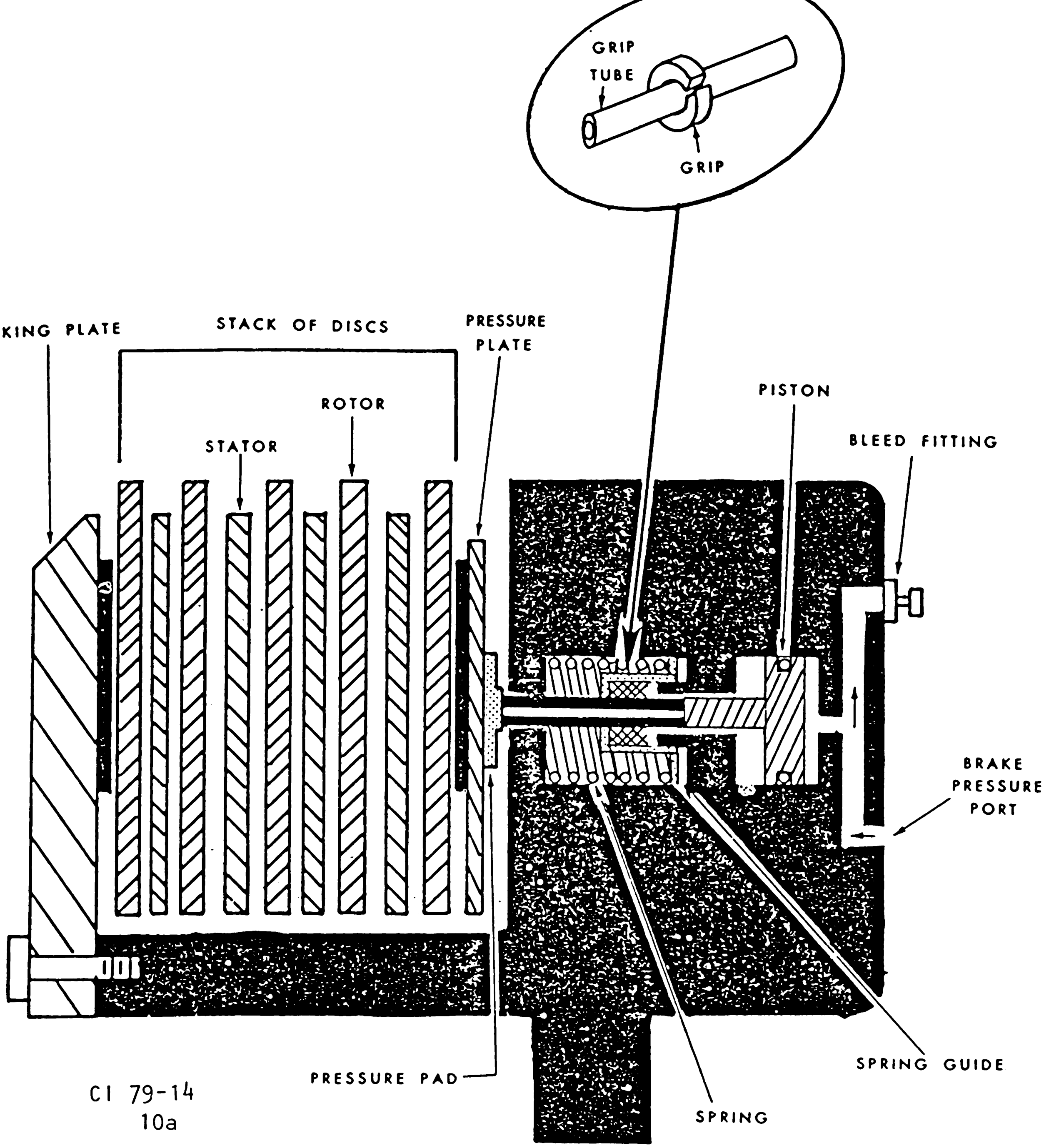


Figure 3–7. Multiple disc brake (internal parts).

5. Explain what precautions should be observed when installing rivets on the wear pads of this brake.

6. Which test just discussed would simulate the back pressure in a pressurized reservoir?

638. Describe procedures to follow during the bench check and repair of a hydraulic filter assembly; then specify the tests to be performed for checking specific items of the filter assembly.

One of the items you may find malfunctioning in the hydraulic system is the filter assembly. This could be from leakage (internal or external), filter element dirty, or the filter bypass malfunctioning. Let's assume that the filter assembly has malfunctioned and you want to bench check and repair it. After removing it from the system, you should take it to the shop. Then research the part and find the proper technical order.

Bench Check of Filter Assembly. In the technical order you will find specific steps to follow, as we stated earlier in Volume 1. Let's go over these steps, which are stated in the technical order, as we bench check and repair this item. First, no special tools are necessary for repair of the filter assembly selected for discussion, although a dummy filter element or equivalent will be necessary during testing. See figure 3-8. A hydraulic test stand capable of producing sufficient pressure and flow will be required also, plus a filter element cleaner (if the element is the reusable type). Refer to Figure 3-9 as we discuss the disassembly of the unit. Disassembly in the order of the key index numbers assigned to the exploded view in Figure 3-9. Clean all parts (less filter element) with appropriate cleaning solution, and dry with filtered compressed air. The filter element, if reusable, will be cleaned by using the Sane 50 or equivalent. If the element is a throwaway item, of course it will not be necessary to clean it. After cleaning all parts, inspect them for corrosion, scoring, cracks, distortion, and other signs of damage or excessive wear. Make sure that all ports and passages are clean and unobstructed and that all threads are clean and undamaged. Replace all parts which are defective or damaged and cannot be repaired. Also replace all seals removed during disassembly with new seals. Polish out minor scratches or corrosion on nonsealing surfaces, using the specified abrasive cloth. Prior to reassembly, lubricate all threaded parts and packings with a light coat of the specified lubricant. Then reassemble the parts in reverse of disassembly of the filter assembly.

Testing. Unless otherwise specified, all tests will be performed using hydraulic fluid, MIL–H–5606, filtered through a 2 micron filter. The temperature of the fluid should be maintained at specified limits for best results. Also, care should be taken to insure that all test equipment and fluids are clean to prevent filter contamination.

Bubble test. For those elements that are reusable, you should perform a bubble test to determine if the filter element is serviceable. Install the filter element in a bubble tester (fig. 3-10). With the filter element immersed in the tester, as shown, increase air pressure slowly and check for air bubbles coming from the element. The specific TO will indicate the allowable leakage.

Differential pressure indicator test. Remove filter bowl and filter element, and install a dummy element. Insure that a red indicator button is pushed in. Connect the IN port of the filter assembly to a hydraulic test, as shown in figure 3-11. Vent the OUT port to the atmosphere. Gradually apply pressure to the filter inlet port until a specified amount is reached according to the TO. When the specified amount is reached the red indicator button should rise. With the pressure maintained, attempt to reset the differential pressure indicator button. The red indicator button should rise when released. Reduce the inlet pressure to zero and depress the differential indicator button. The red indicator button should remain depressed.

Relief valve operation test. With the dummy element still installed and hooked to the test stand, as shown in Figure 3-11, slowly raise test pressure until fluid flows from the OUT port. This will indicate the cracking pressure of the relief valve (bypass valve). Slowly reduce IN port pressure and check relief valve reseating pressure. If

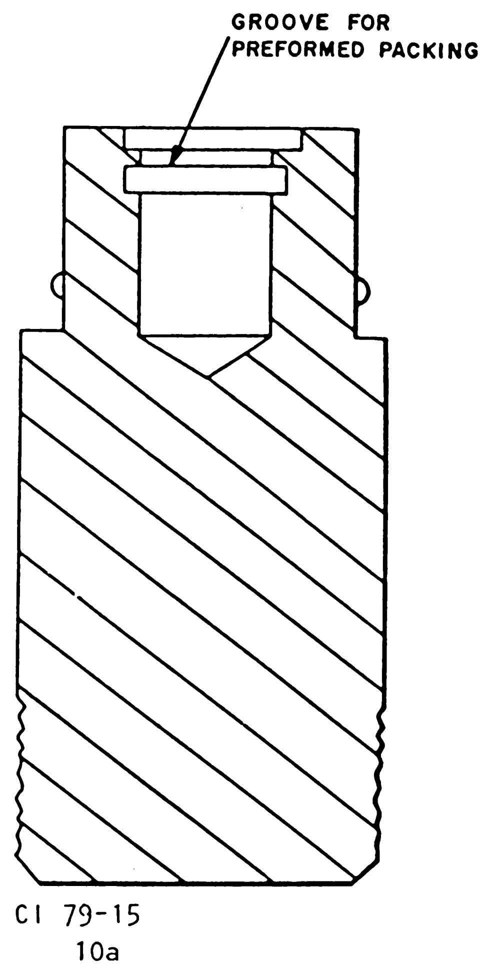


Figure 3–8. Dummy filter element.

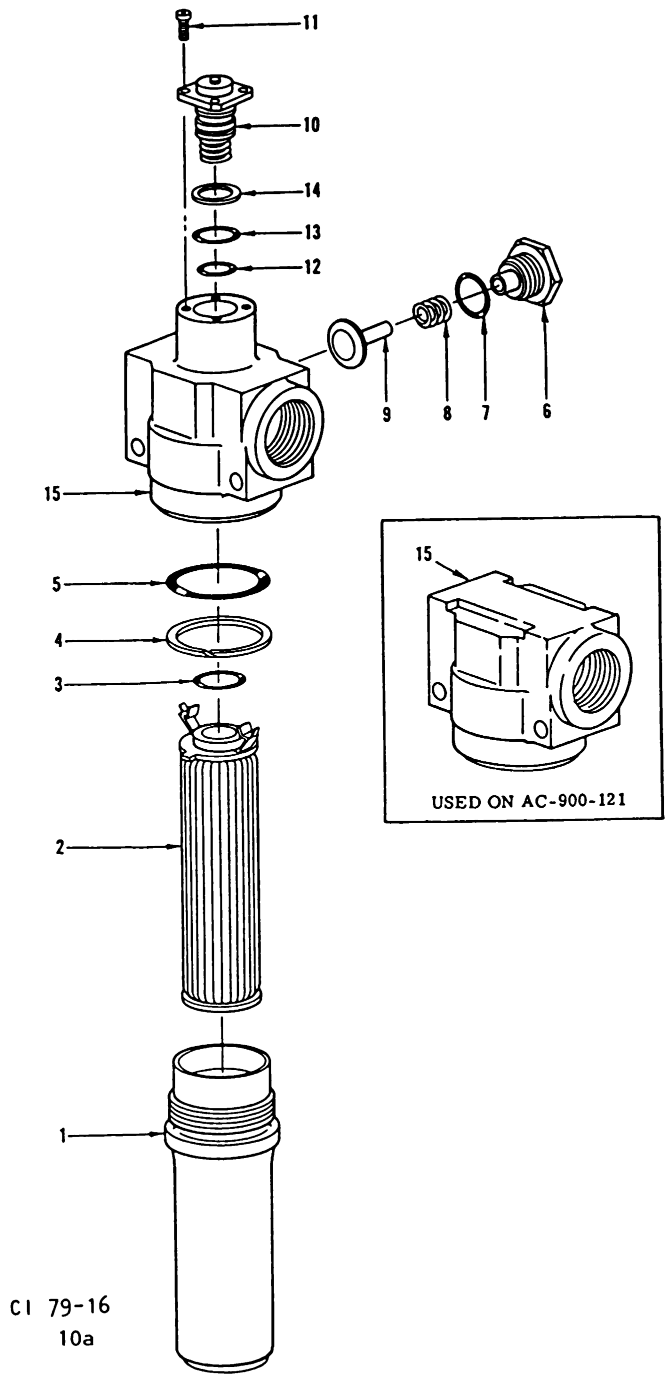


Figure 3–9. Filter assembly breakdown.

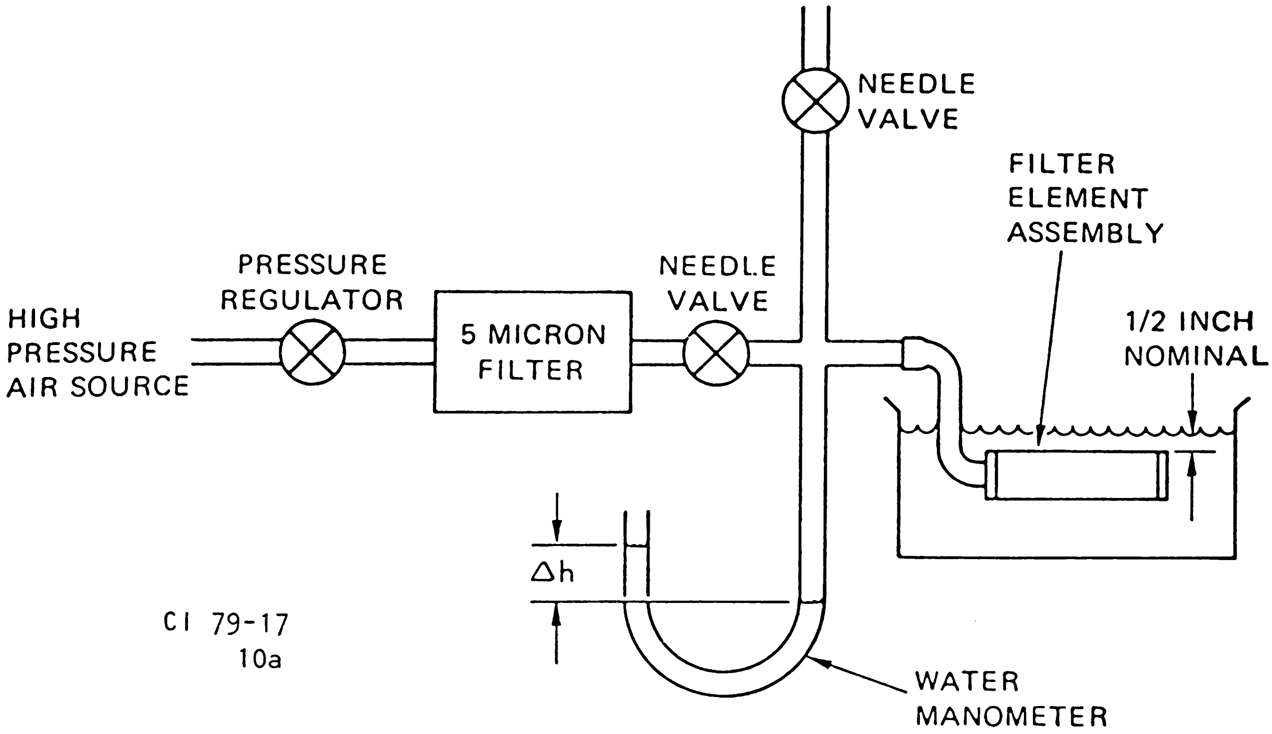


Figure 3–10. Bubble test.

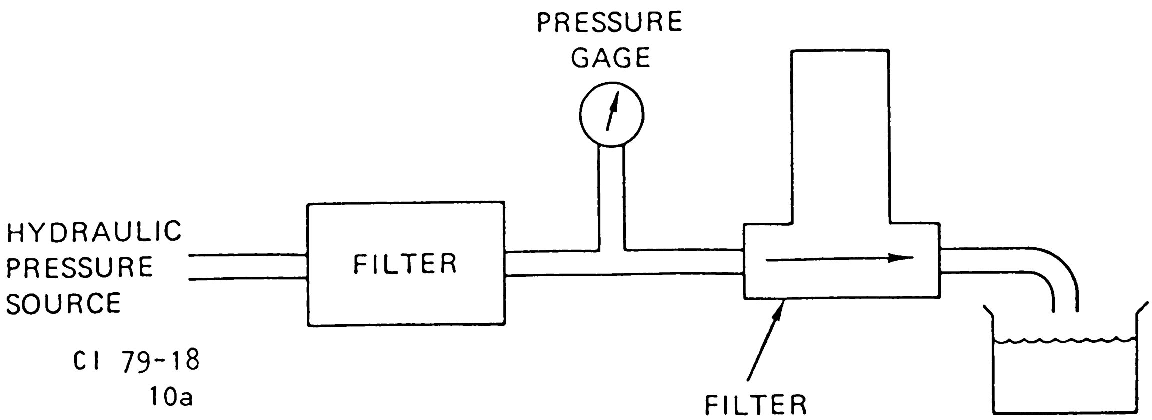


Figure 3–11. Differential pressure and relief valve operation test.

reseating pressure is incorrect check the spring, seating surfaces, and condition of packings. After satisfactory completion of the relief valve test, remove the dummy element installed earlier and replace it with the specified element.

Proof pressure test. With the filter assembly still connected to the test stand, disconnect the OUT port line and cap or plug to the port. Then bleed air from the filter by slowly applying IN port pressure while opening the OUT port cap or plug. Once all the air has escaped, tighten the cap or plug. Gradually increase source pressure to 4500 psi and hold for approximately 2 minutes. Examine the filter assembly for evidence of external leakage and/or permanent deformation. Repeat this test several times if necessary. When you have completed the test, remove the cap or plug from the OUT port.

Flow test. Install the filter assembly in the hydraulic test set-up as shown in Figure 3-12. Notice that a gage is installed in both the IN and OUT ports. Notice also that a flowmeter is installed in the OUT port. Now, apply pressure to the IN port to obtain a specified amount of flow from the OUT port. The net pressure drop across the filter should not exceed a certain amount (such as 18 psi). If the pressure drop is excessive, check for obstruction within flow passages of the head. The filter element may also be defective or dirty.

After satisfactory completion of all tests, wipe the filter down and safety wire. If the unit is to be stored, fill it with preservative fluid MIL–H–6083 and plug all ports.

Exercises (638):

1. What test will be performed to see if the filter element is serviceable?

2. If the filter assembly is leaking externally, which test should be used to determine this?

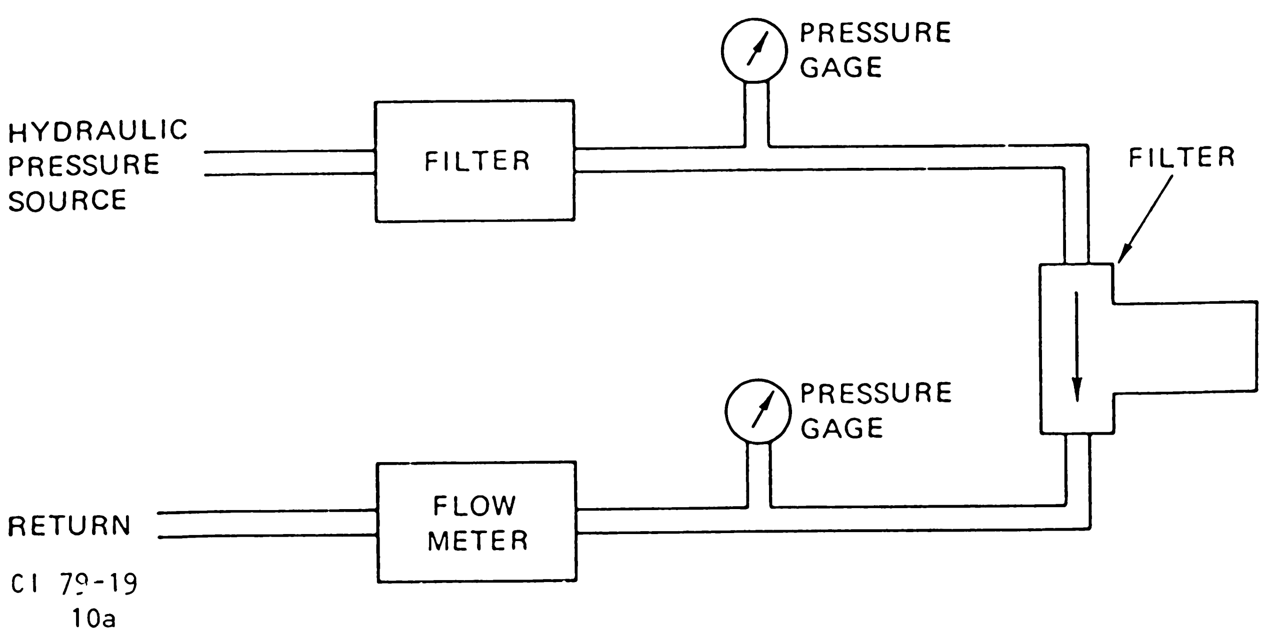


Figure 3–12. Filter assembly flow test.

3. Why is a dummy element used during testing of the filter assembly?

4. How are nonsealing surfaces of the filter assembly repaired?

Aircraft Flight Control Systems

AFTER A touch-and-go landing, the pilot noticed a rolling tendency and a heavy left-wing condition. The situation deteriorated until full right stick and rudder would not maintain wing-level flight. The pilot radio transmitted the difficulties and ejected while the aircraft was rolling out of control. The pilot landed uninjured, but the aircraft was destroyed.

An investigation revealed that the accident was caused by a missing cotter pin. The cotter pin for the control bolt connecting the right-wing aileron servo valve to the push rod had either not been installed or had been installed incorrectly. This allowed the nut to come off and the bolt to work out. The uncontrollable servo valve then caused the actuator to drive the right aileron to the FULL DOWN position and keep it there. This resulted in a complete loss of aileron control.

No systems in the aircraft require more reliability of operation than do the flight control systems. The flight control systems must function properly. If they do not, the aircraft can become an object of destruction and the pilot can be injured or killed. For this reason, flight control systems have always been of great concern to the manufacturer. With this in mind, let's review the flight control systems.

Flight controls are broken down into two basic categories, primary and secondary flight controls. Primary flight controls are ailerons, spoilers, rudder, and stabilator or elevator. Some examples of secondary flight controls are flaps and speed brakes. Most primary flight controls on modern aircraft have some type of automatic flight control system.

4-1. Flight Control System Description

"You can have power steering on this model for just a little more," the salesman said. You think it over. You think how nice it would be to be able to park in those tight parking places without all that twisting and tugging at the steering wheel. You think how nice it would be not to have that feeling of exhaustion after a long drive. You wouldn't be without power steering now. This also applies to modern aircraft, as we shall see.

Terrific pressures are exerted on the control surfaces (ailerons, stabilators, rudder, etc.) of today's supersonic aircraft. Powered control surfaces allow the pilot to overcome these pressures with ease. Many such systems used on modern jet fighter aircraft are equipped with automatic flight control systems that accomplish complex flight maneuvers. Sloppy inspection and maintenance of the basic flight control systems not only result in multiplication of error under automatic control, but have also at times resulted in serious accidents. In this chapter, we review fundamentals of basic flight control systems and applications used in more sophisticated control systems with emphasis on inspection and maintenance.

639. Define camber in relation to an airfoil, and specify how the aerodynamic forces act upon the lift necessary for flight.

Principles of Flight. To understand the job, the pneudraulic specialist must have some knowledge of the principles of flight. No doubt, mankind got the idea of flight from watching the birds soar gracefully overhead. The early attempts at flight were, for the most part, fantastic, if not fatal. We even tried to imitate the birds by attaching wings to our arms and shoulders. It just did not work, because in the early attempts to fly, we didn't know enough about aerodynamics. First, let us review the characteristics of an airfoil and the forces acting upon it in flight.

Airfoils. Figure 4-1 shows a typical airfoil. Note that the two edges of the airfoil differ in appearance. The edge that faces into the wind, in flight, is called the leading edge. The other edge is called the trailing edge. A reference line often used in discussing an airfoil is the chord line. This is a straight line drawn through the airfoil. The line connects the farthermost points of the leading and trailing edge. It is about parallel to the longitudinal axis of the aircraft. A most important factor of an airfoil's lifting ability is camber. Camber is the curve of the surface of an airfoil from the leading edge to the trailing edge. Notice, in Figure 4-1, the upper camber is longer than the lower camber. This difference has an effect on the amount of lift (and drag) the airfoil produces.

Aerodynamic forces. Now let's review the four aerodynamic forces acting upon an aircraft: lift, weight, thrust, and drag. The lift of the airfoil acts upward at a right angle to the direction of the relative wind. Relative wind is the airstream striking the moving airfoil. The weight (gravity) acts vertically downward from the center of the gravity of the aircraft. Thrust is the force that moves the aircraft forward during flight. Drag is the resistance of the atmosphere to the aircraft's forward motion. When the aircraft is in straight and level unaccelerated flight, the lift equals the gravity and the thrust equals the drag. Figure 4-2

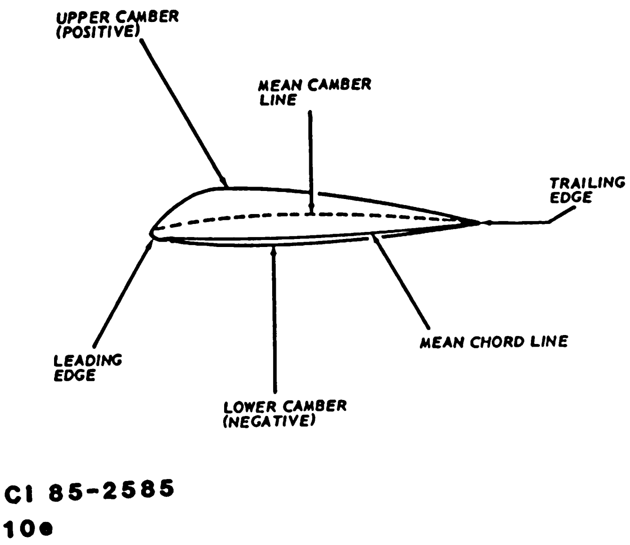


Figure 4–1. Airfoil.

shows how the opposing forces balance each other. The lift forces the airfoil up; at the same time, the resistance (drag) pulls the wing backward.

The other two forces, thrust and weight, affect the airfoil movement. The thrust causes the airfoil to move forward. The weight (gravitational pull) causes the airfoil to fall toward the earth. As you will note, the forces act in different directions and balance each other. If the lift is as great as the weight, the aircraft neither rises nor falls (climbs nor dives); if the thrust is as great as the drag, the aircraft does not move either faster or slower; the speed is constant. To go faster, we merely make the thrust greater than the drag, and the aircraft accelerates. Soon the thrust and drag again equalize. Now the aircraft no longer accelerates but moves ahead at a constant speed, but faster.

The laws of lift and the venturi. The last two principles to consider in our review of flight are the laws of lift and of the venturi. The first law can best be illustrated by holding your hand out of the window of a moving automobile. As you tilt your hand, the force of the air against your hand has a tendency to move it. The airfoil, in this case, is your hand, and it deflects the wind. This action creates a pressure on the lower surface of your hand, forcing it upward and backward (lift and drag). The second law relates to the venturi principles, which you learned about in Volume 2. When an airfoil moves through the air, both the airfoil shape and angle of attack cause the air to be deflected. The

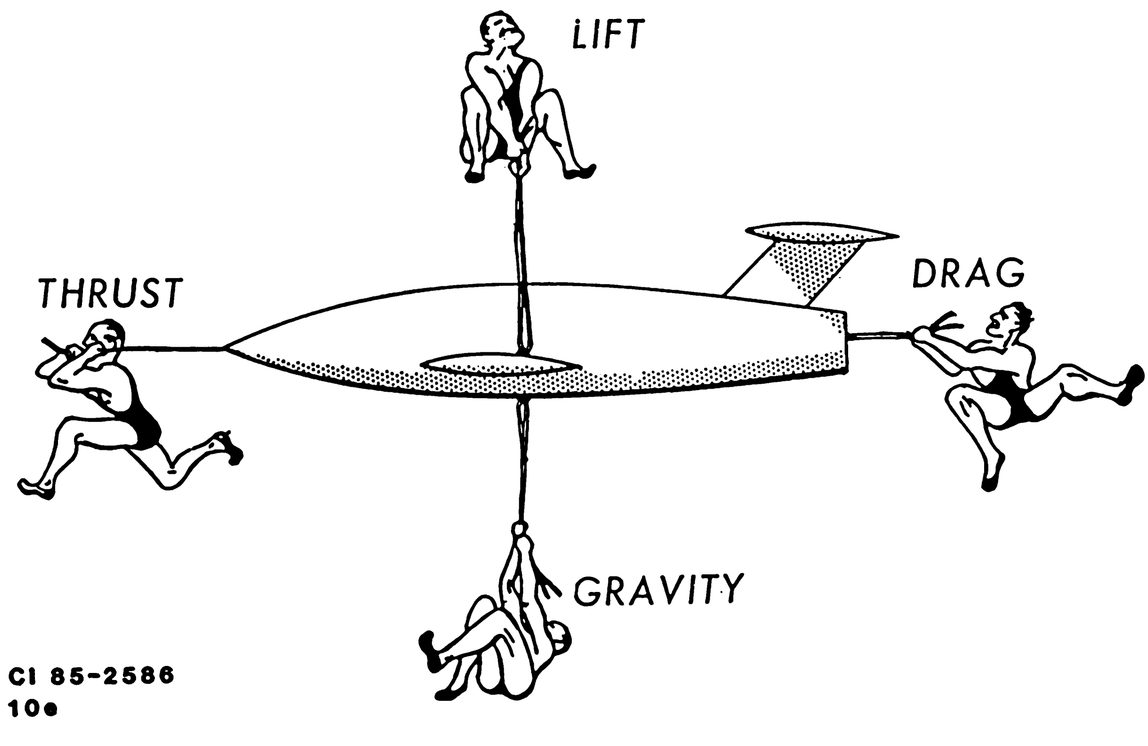


Figure 4–2. Aerodynamic forces.

deflection slows the air below the airfoil, causing a high-pressure area under the surface. The air moving across the upper surface of the airfoil travels a longer distance. This causes an increase in air velocity. This increase in velocity produces low pressure next to the upper surface of the airfoil. In this manner, a pressure differential acting on the top and bottom of the wing creates the lift. As the speed of the airflow increases, the pressure differential (and lift) also increases.

We have already pointed out that drag is the resistance of atmosphere to the airfoil's forward motion. The drag will always act parallel to the relative wind. The relative wind is the direction of the airflow with respect to the airfoil. If an airfoil is moving forward horizontally, the relative wind moves rearward and upward. The angle of attack of an airfoil directly controls the distribution of pressure above and below it. The angle of attack can be defined as: the angle between the chord of an airfoil and the direction of the relative wind. Whenever one of the conditions is changed, it will affect another. For example, if speed is increased, angle of attack will change. This speed increase causes a pressure change above and below the airfoil. The pressure change causes the aircraft to climb because of a greater lift from the airfoil. To maintain constant lift, the airfoil's velocity must be decreased as its angle of attack is increased. You can see from this, then, how the necessary lift for flight is produced.

Exercises (639):

1. Define camber in relation to an airfoil.

2. What aerodynamic force moves the aircraft forward during flight?

3. What force will pull the wing of an aircraft down?

4. What aerodynamic force will increase as the speed of the airflow across the airfoil is increased?

5. What force will always act parallel to the relative wind across the airfoil?

6. What controls the distribution of pressure above and below the airfoil?

7. When will lift be equal to gravity and thrust be equal to drag?

8. For the aircraft to move at a constant speed, what two forces must be equal?

9. How is the lift of a wing created?

640. Specify the location and use made of the flight control surfaces.

Flight Characteristics. There are three axes about which an aircraft may turn, as shown in Figure 4-3. These axes are imaginary lines passing through the aircraft's center of gravity. You might think of these axes as imaginary axes around which the aircraft turns like a wheel. Each of the axes is perpendicular to the other two. The axis that extends from the nose of the fuselage to the tail is the *longitudinal* axis. The axis that extends crosswise, from wingtip to wingtip, is the *lateral* axis. The axis that passes vertically through the center of gravity is called the *vertical* axis. The motion about the longitudinal axis is called roll. The motion about the lateral axis is call pitch. When the attitude of an aircraft is changed in flight, it will move around one or more of its axes.

Now you have become familiar with a few of the characteristics of flight and the different forces that act on the aircraft. Next look at the various surfaces used in controlling movements of the aircraft in flight.

Flight Control Surfaces. It is very simple to change the direction of a bus, car, or truck by merely turning the steering wheel. Changing the direction of an aircraft as it flies involves the movement of flight control surfaces. These flight control surfaces are located in various areas of the aircraft.

Elevators. The elevators, as shown in figure 4-3 center, are used to make the aircraft dive or climb. This is done by controlling the angle of the surface with respect to the air flowing over it. The elevators are hinged to the trailing edge of the horizontal stabilizer. They are connected so that they always operate together. Forward and aft operation of the control stick moves the elevators up and down. This movement controls the aircraft about the lateral axis. Downward force on the tail causes the nose to rise and increases the wing angle of the attack. This increases the lift and causes the aircraft to climb if the speed is maintained. If the pilot moves the control forward, the elevators move downward. The lift will decrease and the aircraft will lose altitude.

Rudder. The rudder, as shown in the lower part of figure 4-3, is hinged in a vertical position at the trailing edge of the vertical stabilizer. Controlled by the movement of the rudder pedals, it guides the movement of the aircraft about the vertical axis. When the pilot applies pressure on the right pedal, the rudder moves to the right. The tail of the aircraft is thus forced to the left, rotating the aircraft about its vertical axis. When the tail is moved to the left, the nose of the aircraft is moved to the right. Pressure applied to the left pedal reverses the action.

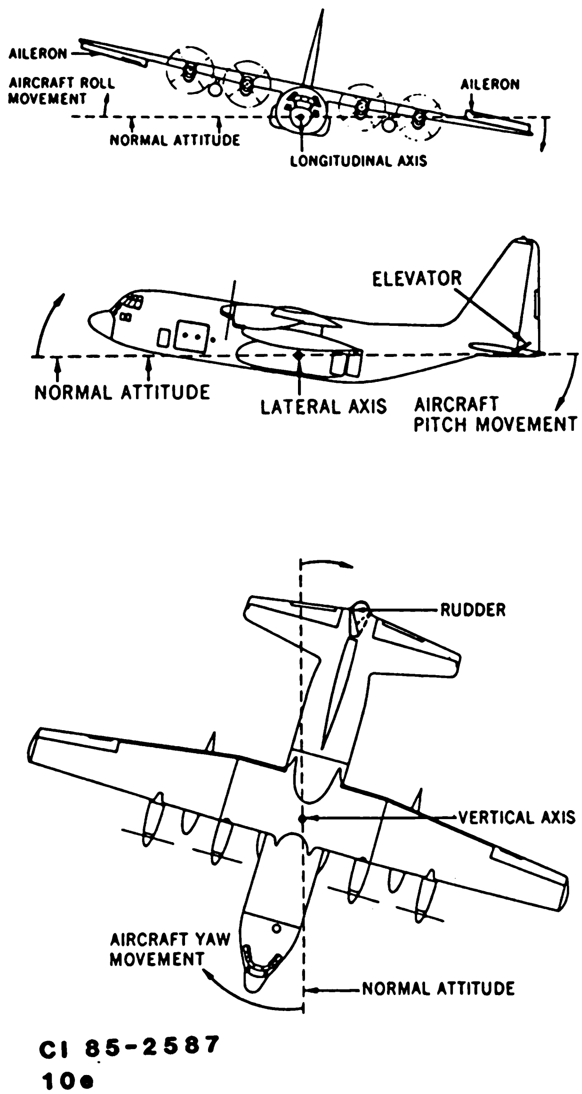


Figure 4–3. Flight axis.

If the pilot makes a turn with a rudder alone, he or she normally finds that the aircraft will sideslip. This is similar to an automobile trying to take an unbanked curve too fast. The skidding is caused by centrifugal force. The pilot prevents this skidding (or sideslipping) by banking. Banking is the coordination of rudder and ailerons in a turn.

Ailerons. The ailerons, as shown on the top of figure 4-3, are located in the trailing edge and toward the tips of the wings. Their movement is controlled by the pilot's control stick or wheel. From the pilot's control, the linkage is arranged so that if one aileron goes up the other goes down. For a right turn, the right aileron is raised, which forces that wing down. The left aileron has moved down which results in more lift on the left wing; the wing then rises.

Movable horizontal stabilizer. During flight at transonic (at speed of sound) speeds, the airflow over the horizontal stabilizer creates shock waves. These shock waves form air fences ahead of the elevators that result in the loss of elevator control.

To correct this, present-day aircraft are equipped with a movable horizontal stabilizer. It gives the pilot faster and firmer control over the aircraft. The control stick is connected to the horizontal stabilizer through mechanical and hydraulic units. These aircraft have no elevators, and the pilot flies the aircraft with the horizontal stabilizer. When the stabilizer control stick is moved aft, the stabilizer leading edge moves down and the nose of the aircraft moves up. Figure 4-4 shows the location of the flight control surfaces used on one of today's modern-type aircraft.

Tabs. Tabs are located on the trailing edge of controls such as the elevator, rudder, and ailerons. Their reaction in the airstream, however, is the same in all three cases. For example, we wish to trim an aircraft in pitch. In order to raise the nose of the aircraft, the tab must be moved down. The reason for this is clearly shown in figure 4-5. The primary control surface, in this case the elevator, is hinged to the horizontal stabilizer. The tab, in turn, is hinged to the elevator. A movement of the tab causes a powerful movement to be exerted on the primary control surface. The result of this force is a small movement of the elevator in the opposite direction. Therefore, if the tab is moved down, the elevator moves up. Since the aircraft responds only to the action of the primary control, the tail drops. This raises the nose of the aircraft.

Spoilers. Spoilers are of several different types. In effect, they momentarily destroy or interrupt a part of the lift pattern on a wing. Figure 4-6 shows the action of one type of spoiler.

This spoiler is recessed into the upper chamber of the wing (fig. 4-6). In the top part of figure 4-6, the spoiler is not used. The flow of air over the wing is smooth and uninterrupted, and the full lifting power of the wing is realized. However, assume that a gust of air has caused the left wing to go down. The automatic flight control system instantly sends out a signal for the spoiler on the right wing to rise. By this action, the lift of the right wing is "spoiled" by the turbulence created by the spoiler. The right wing will begin to drop. (See bottom part of fig. 4-6.) Since the spoiler on the left wing is still recessed, the lift on that wing is now greater. This results in the left wing moving itself up to normal level flight. While this is going on, the right-wing spoiler moves back to the recessed position.

An extended spoiler causes drag on one wing, which may cause the aircraft to yaw. Therefore, when the spoiler extends, the rudder may be actuated at the same time to prevent yaw.

Speed brakes. These are used to increase drag to slow the aircraft and reduce landing distance. Several types of speed brakes are in use. The principle of operation is the same for combination or independent systems. Some aircraft use a combination spoiler speed brake system. On others, the systems are independent of each other. When the spoilers are used as speed brakes, both sides rise together. Some of these combination systems also allow the speed brake to be raised in various degrees. Fighter aircraft often use another type. Usually, this is just a large spoiler extended from the lower fuselage area.

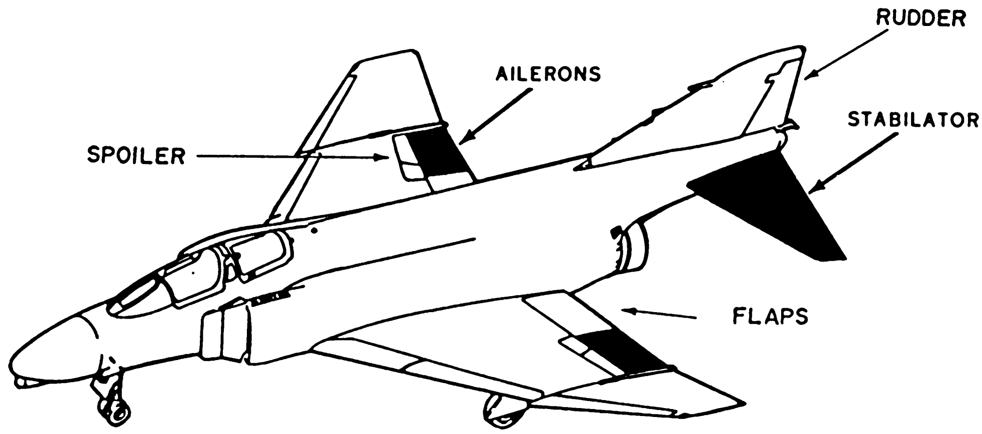


Figure 4–4. Flight control surfaces.

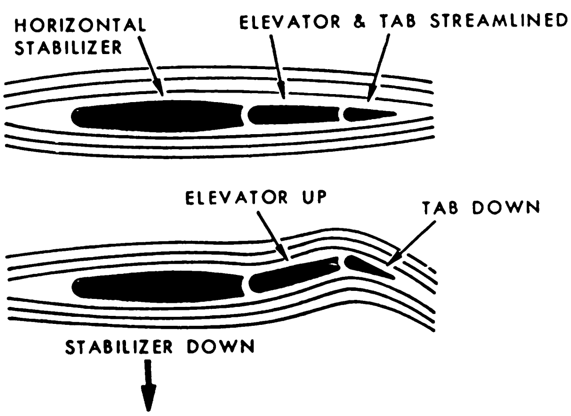


Figure 4–5. Trim tabs.

Wing flaps. The wing flap is a dual-purpose control, used to increase lift and also used to increase drag. Wing flaps are located under the trailing edge of the wings. Normally, about 25 percent flaps down is used for takeoff and full down flaps are used for landing. The increase of lift and drag means a slower landing speed and a steeper gliding angle.

Besides the plain flap, there is the split flap, figure 4-7, center, consisting of a hinged section of only the lower chamber. The upper chamber remains stationary as part of the wing structure while the lower section drops. The leading edge flap is hinged to the front of the wing structure.

The most efficient type of flap is the Fowler flap, figure 4-7, bottom view. In this type, the flap moves down and slides aft on a track at the same time. This type is more effective, because it increases wing camber.

Exercises (640):

1. Forward and aft movement of the control stick controls the movement of the aircraft about which axis?

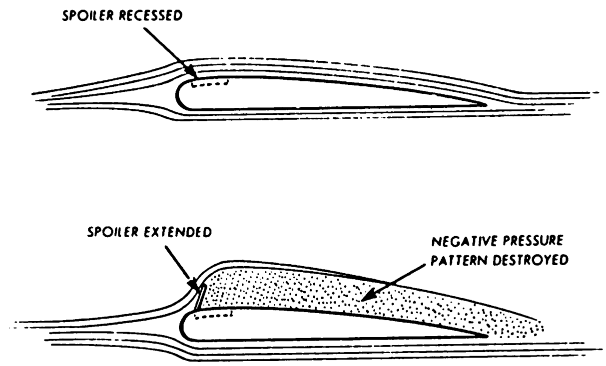


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Figure 4–6. Spoilers.

2. What control surface is hinged to the trailing edge of the vertical stabilizer?

3. Which primary flight controls are located in the trailing edge and near the tips of the wings?

4. When the control stick is moved to the right, which direction do the ailerons move?

5. What flight control surface controls the aircraft about its vertical axis?

6. Where are tabs located?

7. What control surface will momentarily interrupt or destroy a part of the lift pattern on a wing?

8. What control surface, when extended, will cause the aircraft to yaw because of the drag it may cause on one wing?

9. What is the purpose of speed brakes?

10. What are the two purposes of the wing flaps?

11. Where are the wing flaps located?

12. What flight controls control the aircraft about the lateral axis?

13. What flight control can be used to trim an aircraft in pitch?

14. If an aircraft has no elevators, what gives the pilot control of the aircraft about the lateral axis?

641. Specify the use made or purpose of various systems that aid the pilot in flying the aircraft.

Artificial Feel System. In very early flight control systems, the pilot moved the control stick and the mechanical linkage (push-pull rods) operated the control surfaces. With this system, the pilot has a definite feel of the amount of air pressure that he or she is forced to

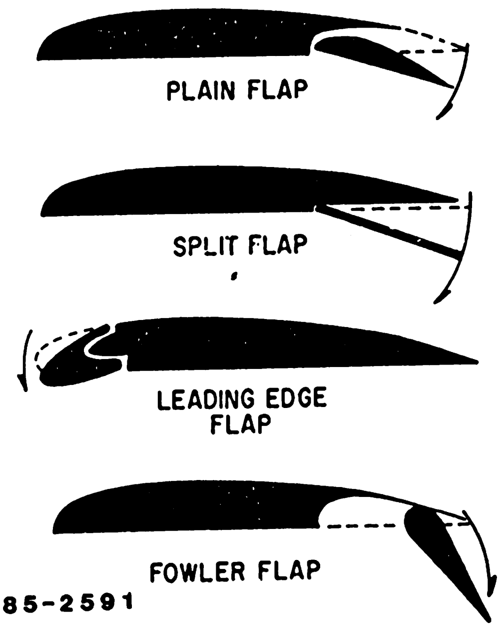

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Figure 4–7. Types of flaps.

overcome with control stick operation (fig. 4-8). This, however, turned out to be one disadvantage of the direct manual system because the airload forces on the control surfaces would vary with the speed of the aircraft. With the advent of new and faster models of aircraft, such high airloads are encountered that the task of flying the aircraft exceeds the physical capabilities of the pilot. To compensate for the increased airloads, a powered flight control system using hydraulic pressure was developed. With this type of system, the pilot does not move the control surface directly but only positions a control valve. The control valve directs hydraulic fluid to either side of an actuating cylinder. It was found that even though it made it easier to move the control surfaces, the pilot had no feel of the control surface airload. This usually made the pilot demand too much control surface movement when moving the control stick. To compensate for this, a large spring was installed to the mechanical linkage to simulate an artificial aerodynamic load. This system is called the artificial feel system.

Electrical Trim System. The trim system is used to make minor movements of the flight controls rather than using the control stick. The trim switch for both the elevators and ailerons is normally located on the control stick, figure 4-9. The trim switch is used to energize electrical motor actuators that position the hydraulic control valve. Here is how it works. If an aircraft is perfectly balanced, it should be able to fly straight and even when the control surfaces are streamlined. If the aircraft becomes unbalanced, a control surface must be moved in order for the aircraft to fly straight and level. When an aircraft is not balanced it is said to be "out of trim." When the trim switch is positioned, it moves the control surface just enough to compensate for the out-of-trim condition. This causes the aircraft to become balanced again.

Automatic Flight Controls. One system of vital importance on a modern aircraft is the automatic flight control system (AFCS). The AFCS is broken down into two major parts: stability augmentation (stab aug) and autopilot (A/P) systems.

Stability augmentation. The stability augmentation system serves two functions. First, it automatically coordinates the turns and smoothes out the bumps as the aircraft passes through turbulent air. Second, it improves the handling characteristics when the pilot is flying the aircraft manually. On commercial aircraft, the stab aug system is used to give the passengers as smooth a ride as possible. On an Air Force fighter or bomber, the stab aug is used to make the aircraft a stable platform from which weapons can be launched.

Autopilot. The autopilot system on military aircraft is used for pilot relief. That is, on long flights it can be used to fly the aircraft automatically along a predetermined course selected by the pilot. The electronic equipment in the autopilot system controls the aircraft in various modes. A brief explanation of each mode is listed below.

- Attitude hold. Pitch or roll is the basic autopilot mode of each axis. The attitude hold will hold the aircraft at the reference attitude until another mode is selected.
- Altitude hold. In this mode, the autopilot automatically maintains the aircraft at a constant barometric altitude.
- Mach hold. This mode automatically maintains the mach speed of the aircraft. This is done by varying the pitch attitude of the aircraft.

Exercises (641):

1. What is used in the flight control system to prevent overcompensating when the control stick is moved?

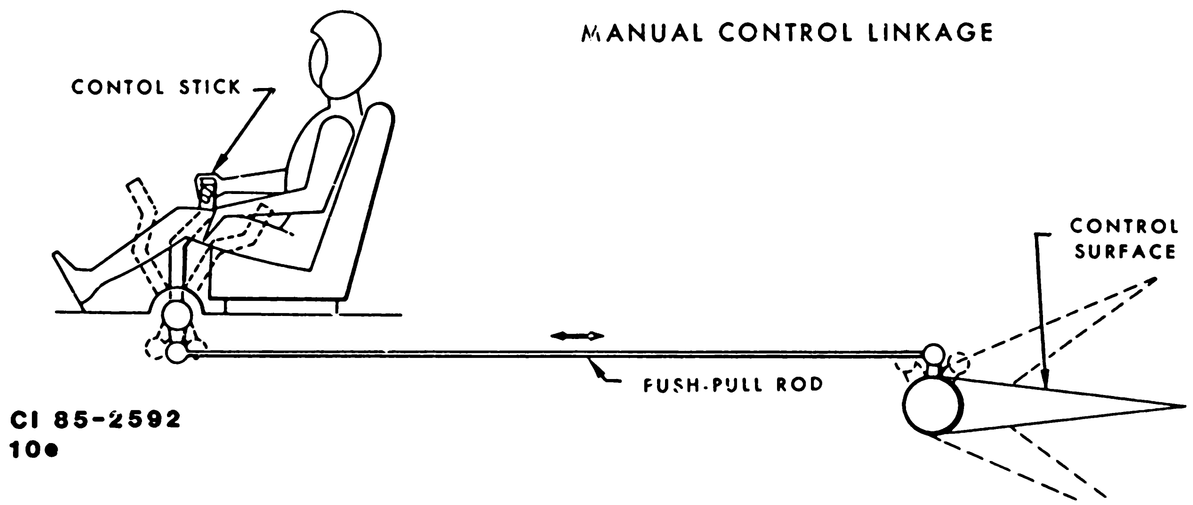

Figure 4–8. Mechanical flight controls.

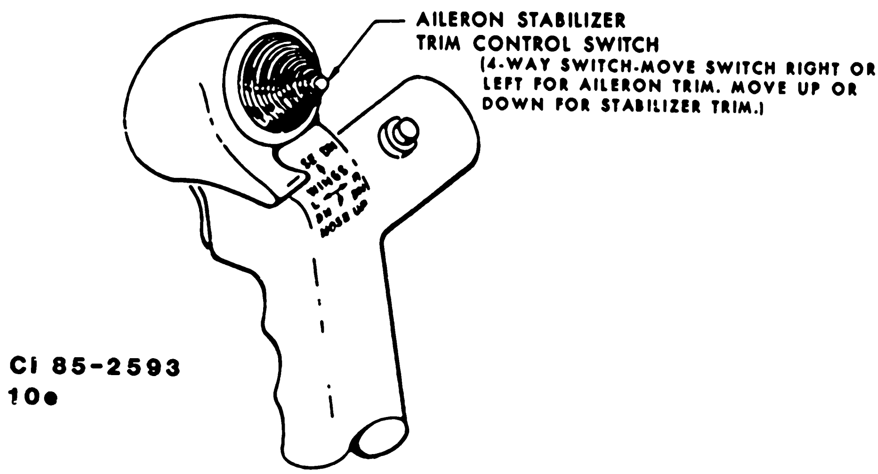

Figure 4–9. Trim switch.

2. Can the force of the air against the control surface be felt by the pilot when a hydraulic power system is used?

3. To compensate for small unbalanced conditions of the aircraft, what can be used?

4. What are the two main systems contained in the AFCS?

5. What is the purpose of the stability augmentation system of an Air Force fighter or bomber?

6. What is the purpose of the autopilot system in most aircraft?

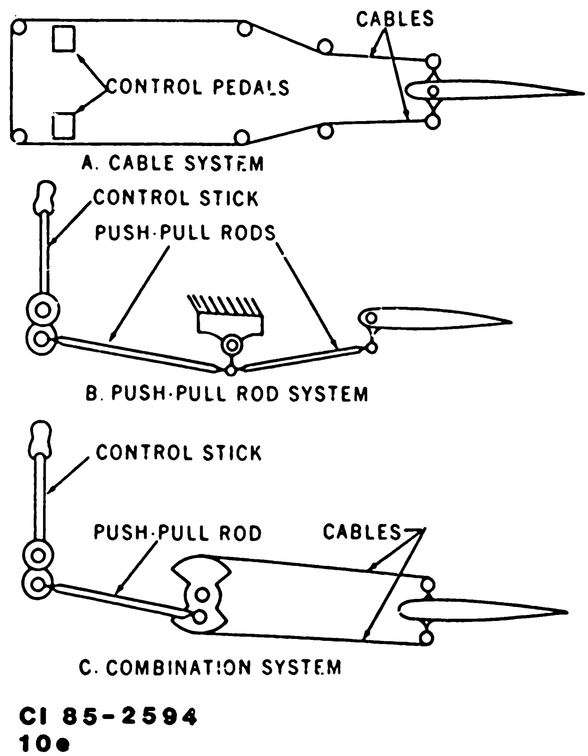

Figure 4–10. Types of linkage.

642. Identify the control linkage units and their related functions.

Types of Linkage Systems. Figure 4-10 illustrates the classification of control linkages according to construction: The three types of cable systems, push-pull rods, and various combinations of the two.

Cable system. On jet aircraft, the cable system is generally used to operate the rudder. The cables are flexible. This permits routing around obstacles by the use of pulleys, quadrants, and bellcranks. They can be installed over long distances without a great degree of sagging. However, they must be worked in pairs—one to move the control surface in one direction and the other to move it in the opposite direction. There is no lost motion, since the cables are stretched tight and very little play is present in the system controls. As a consequence, cable-operated flight controls respond quickly and accurately to cockpit control movement.

Push-pull rod system. In a push-pull rod system, the surface control is connected to the cockpit by means of rods. The movement of the cockpit control is transferred to the control surface by either a push or pull force on the rods.

In addition to gaining greater rigidity in the control linkages, push-pull rods are less affected by temperature change than cables. Also, only one push-pull rod is necessary to perform the same function requiring two cables. In some cases, however, push-pull rods are difficult to rotate through or around obstacles to ready the control surface to be actuated.

Combination system. The combination of both cables and push-pull rods is used where convenience demands. Since this combination uses both cables and push-pull rods, it makes use of most of the control linkage units used in both the other systems.

Control Linkage Units. Control linkage units are those items needed to route and connect the cables from the control device in the cockpit to the surface or unit.

Cables. An aircraft control cable is simply a wire rope made of flexible steel, usually corrosion-resistant, and it varies from 1/16 to 3/8 inch in diameter. Cables measuring 1/8 inch or larger in diameter are normally used in primary flight control systems. Smaller cables (less than 1/8 inch in diameter) are generally used in trim and engine control systems.

Cables are prefabricated to fit either from turnbuckle to turnbuckle or from turnbuckle to unit. The strength of a cable is usually 50 percent in excess of the design loads to be sustained. Because of this and because of the number of individual wires, failure of the cable is never abrupt but is progressive over periods of extended use. Some broken wires may appear in the cable soon after it is put into service, usually happening because some wires are under more tension than others. Usually, after the first few wires break, it will be quite an interval of time before any more broken wires show up. It has been proven that the loss in cable strength due to broken wires depends on their concentration within an area rather than the total number of breaks in the cable.

Cable hardware and fittings. To make proper use of the cables connecting the controls, certain types of fittings, called terminals, are attached to the cable ends.

Four methods are used to attach the terminals to the ends of the cables—swaged, sweat-soldered, wrap-soldered, and woven splice. The swaged terminal is standard for most jet aircraft cables carrying light loads. The wrap-soldered splice and the woven splice are used only as emergency replacements for the other two.

Turnbuckle. This device is used to join cable ends and to adjust cable tension. The turnbuckle barrel is threaded with internal left-hand and right-hand threads at opposite ends. The cable terminals are also threaded with left-hand and right-hand threads. Turning the barrel will vary the tension on the cable. In this way the cables are either loosened or tightened, depending upon which way the barrel is turned.

Turnbuckles are purposely located and grouped in the aircraft to make maintenance and inspection easier. Generally, in the fuselage the right-hand threaded end of the turnbuckle barrel faces toward the front of the aircraft, and in the wings it points toward the wing tips. Some barrels are marked on the left-hand threaded end with either a circular groove or a knurl.

Cable quick-disconnect unit. Sometimes this unit is called a cable tension release fitting. It is installed in the cable system on many jet fighters to permit a quick and easy disconnect and reconnect to the cable system without the necessity of resetting the cable tension. On most fighter aircraft, many quick-disconnect units are found at the fuselage break point. Since engine change may require that the aft fuselage be separated at this point, it may often be necessary to disconnect rudder trim and other flight control cables. When the disconnect unit is loosened, the tension on the cable is released, allowing the cable to be disconnected. Closing the cable quick-disconnect unit restores the cable to its original length and tension.

Pulleys. These components, used on flight control systems, are made of phenolic or other nonmagnetic materials. As control cables scarcely ever run straight from one point to another, pulleys are used to change direction, to change the angle of pull, or to clear obstacles. Most pulleys are made with sealed bearings and require no further lubrication.

Fairlead. This serves to keep the cable controls from coming in contact with structural parts of the aircraft. It reduces vibration and sag. It also permits cables to pass through bulkheads without coming into direct contact with the bulkhead, thus preventing chafing and wear to the cable.

Pressure seals. These are used to prevent loss of cabin pressure when cables are routed through pressurized areas on the aircraft. These units are usually made of soft rubber material and clamp around the cable to make a pliable, airtight seal.

Quadrants and bellcranks. These units are used to transmit motion about an axis and to change the direction of force of a cable or push-pull rod. The use of one or the other is usually determined by the location of the control, the control itself, and the amount of motion involved.

Stops. These are mechanical devices used to limit the range of movement of a control surface or unit. The stops may be either fixed or adjustable.

Torque tubes. Rods or shafts (torque tubes) are simple machines used to transmit torque or motion about an axis. The drive shaft of an automobile is a good example of a torque tube. Torque tubes are used in flight control systems to transmit force (torque) from one unit to another.

Push-pull rods. These are rigid rods that transmit both push and pull motion. The rods may be adjusted at either or both ends; loosening the locknut permits adjustment by

threading the end fitting in or out as needed. A small drilled hole in the terminal is used to check for engagement of the rod. When a piece of safety wire can be inserted in the hole, the terminal is not engaged enough.

Exercises (642):

1. Identify the control linkage units in column B by matching them to their function listed in column A.

Column A	*Column B*
____ (1) Wire rope made of flexible steel that is used to operate the control surfaces.	a. Push-pull rod.
____ (2) Used to join cable ends and adjust cable tension.	b. Pulley.
____ (3) Used to quickly disconnect and reconnect to the cable system.	c. Fair lead.
____ (4) Will change cable direction, angle of pull and allow cable to clear obstacle.	d. Stops.
____ (5) Prevents a loss of cabin pressurization when cables are routed through pressurized areas.	e. Cables.
____ (6) Will transmit motion about an axis and change direction of force of a cable or push-pull rod.	f. Bellcranks and quadrants.
____ (7) Limits the range of movement of a control surface or unit.	g. Turnbuckles.
____ (8) Transmits torque or motion about an axis.	h. Torque tubes.
____ (9) Transmits both push and pull motion.	i. Cable quick disconnect unit.
____ (10) Reduces cable vibration and sag.	j. Pressure seals.
	k. Cable terminals.

4-2. Primary Flight Controls

It is very simple to change the way an automobile is heading by merely turning the steering wheel. This movement is about the vertical axis. Aircraft directional movement is around three axes—lateral, longitudinal, and vertical—and represents an unlimited number of planes of movement.

Like most self-propelled machines, an aircraft is equipped with the means (flight controls) of controlling its direction of travel. The controls operate well because of systems of cables, push-pull rods, bellcranks, or combinations of these systems. Even the latest aircraft having hydraulically actuated control surfaces are equipped with control linkages. Although they are not necessarily connected directly to the control surfaces, they do control the operation of the control surfaces.

643. Specify the constructional/operational features of a large aircraft that uses shutoff valves in the rudder system.

Larger Aircraft Flight Control Systems. Many larger types of aircraft have a means of shutting off pressure to the flight controls while in flight. This can serve many uses. One use would be if one system was to malfunction, the other system could be shut down. Another could be if the pilot wants to check the system. He or she can shut down one system and check the other to see if it is working properly. The system we have chosen to talk about in this discussion is the rudder boost control system. This particular rudder system, besides being able to shut off the pressure to each of its systems, also has a means of lowering the pressure to the rudder boost pack. We will see how this is done as we go along. Refer to Figure 4-11 as we explain how the system works.

This particular rudder boost system is operated hydraulically by two separate hydraulic systems: booster and utility pressure. In each of these systems, you can find a shutoff valve, diverter valve, pressure reducer, relief valve and pressure transmitter. The boost pack itself consists of a booster control valve and a double-acting balanced actuating cylinder. A filter assembly with a built-in differential filter relief valve is installed in each inlet port to the boost pack. The differential filter relief valve will open when the filter becomes clogged. The manual control parts of the rudder control system consist of rudder pedals, torque tubes, cables, tension regulator, and push rods.

Operation. With the aircraft engines running, hydraulic pressure is available to the rudder boost system. In order for pressure to flow to the boost pack, the two shutoff valves must be opened. In order to close the valves, the rudder utility switch or rudder boost switch must be moved to the OFF position. When this happens, electrical power from the rudder shutoff valves circuit breaker panel can flow to either shutoff valve, depending on which switch was actuated. Notice also that when the switch was placed to the OFF position, electrical power was available to turn on a warning light. So, anytime the shutoff valves are closed, the warning light will be on. Now let's open the shutoff valves again to allow the pressure to enter the booster and utility systems. Notice just past the shutoff valves is another valve, which is called a diverter valve (it diverts pressure). These valves are solenoid-operated, normally deenergized to allow pressure to flow through a pressure reducer. When energized, the full pressure (3000 psi) is sent to the boost pack. The diverter valves are energized by a switch on the wing flaps. Before we go on, let's explain why we want to reduce the pressure to the rudder. When the aircraft is flying at high speeds, the airload against the large surface areas of the rudder creates a tremendous force. If the rudder is forced to move against this force using 3000 psi, the rudder supporting structure could be damaged. To prevent this from happening, the rudder pressure is lowered when the aircraft is flying at high speeds. At low speeds the high pressure (3000 psi) is used to give the aircraft better maneuverability. How is this done? When the flaps are down, this either means the aircraft is taking off or landing.

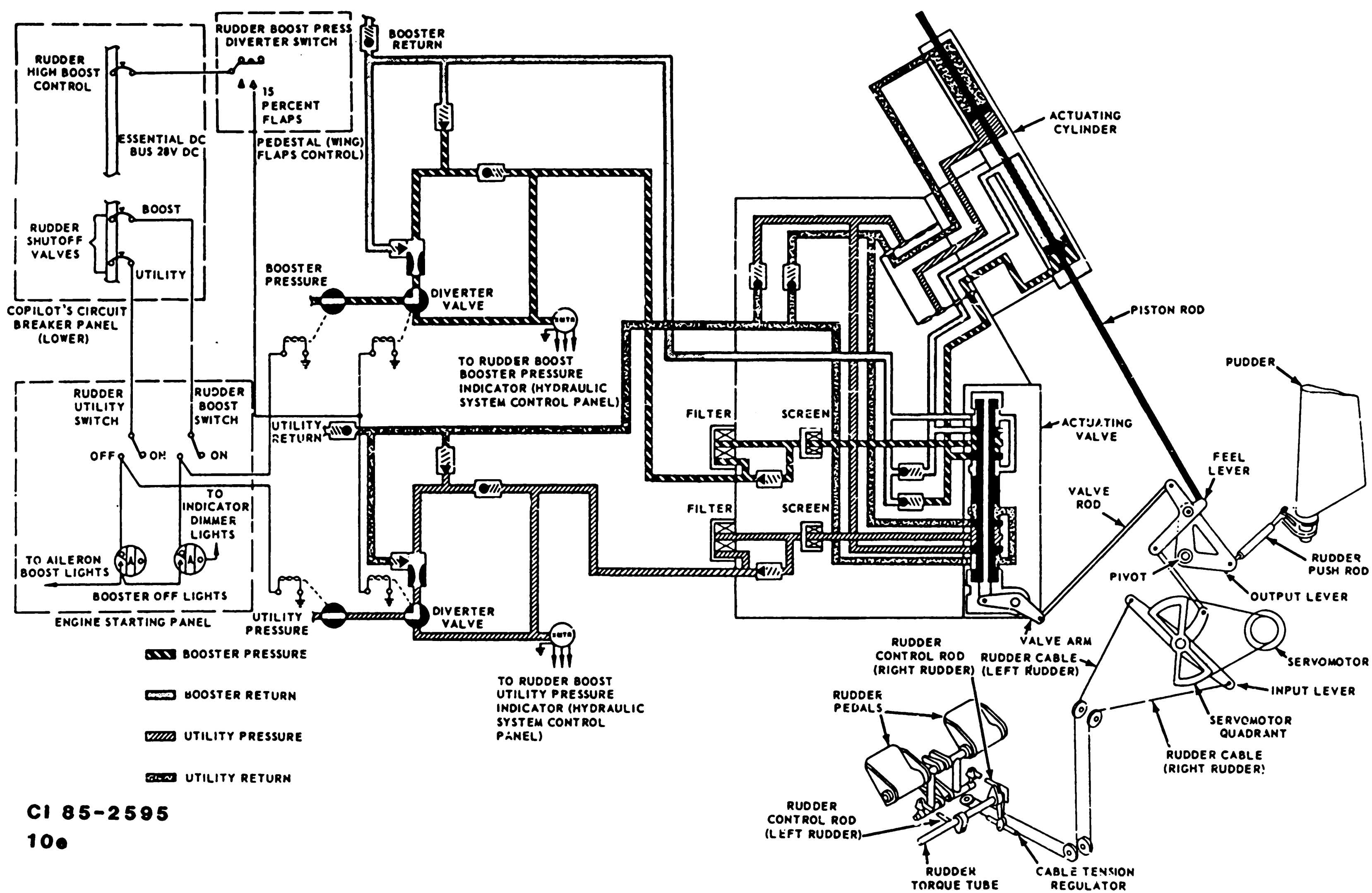

Figure 4–11. Rudder boost system.

A switch located on the flaps will energize the diverter valve.

At this time, we have 3000 psi available to the rudder boost pack. After the flaps are raised (the aircraft is flying at a faster speed), the diverter valves are deenergized. When this happens, the pressure is diverted through the pressure reducers. The pressure reducers reduce the pressure approximately 1300 psi. Downstream from the pressure reducer is a relief valve that will open if the pressure reducer should malfunction. Notice that the pressure transmitter is installed in such a way that it transmits both the full pressure and reduced pressures to the cockpit. In figure 4-11, notice that the diverter valve is deenergized and the pressure is flowing through the pressure reducer and down to the boost pack, through the filters, and to the control valve.

Manual control. The manual part of the rudder control system consists of dual rudder pedals, torque tubes, cables, tension regulator, and a booster system (fig. 4-11). Notice that the booster system consists of control switches, a booster control valve, and actuating cylinder, and a piston rod. During normal operation, rudder boost supplies the major force to move the rudder.

Rudder control is initiated by placing the rudder switches (fig. 4-11) to ON. When these switches are turned on, pressure from the booster and utility systems flows to the booster control valve. Pressing the pilot's or copilot's rudder pedals rotates the rudder torque tube. In turn, control cables attached to the rudder torque tube rotate an input lever. Movement of the input lever is transmitted to the booster control valve by the feel lever and valve rod. When either of the left rudder pedals is moved forward, hydraulic pressure is routed through the booster control valve to the actuating cylinder. In turn, the piston in the actuating cylinder moves the rudder to the left and the aircraft turns left. Movement of the right rudder pedal forward applies hydraulic pressure, resulting in a turn to the right.

When the flight control system is operated on autopilot, electrical signals are sent to the servomotor (fig. 4-11). As the servomotor receives the signals, it positions the servomotor quadrant. It is apparent from figure 4-11 that this produces the same control effect as movement of the rudder pedals. If hydraulic pressure is lost, the rudder can be operated through mechanical force. The lost motion within the control linkages is taken up and rudder pedal movement is transmitted directly to the rudder.

Exercises (643):

1. During normal operation, what force moves the rudders?

2. Why are shutoff valves installed in the rudder boost system?

3. How does the autopilot control the rudder?

4. Why is the pressure to the rudder lowered at high air speeds?

5. How is rudder booster control initiated?

6. How are the diverter valves energized?

7. If rudder boost pressure is lost, how is the rudder operated?

8. If a warning light was on, what would this indicate?

9. If the pressure transmitter is reading 3000 psi, the diverter valve is in what position?

In this section we discuss a typical primary and secondary flight control system. The primary flight control system we discuss is the Aileron/Spoiler system used for roll control. In discussing the Aileron/Spoiler system, we will also deal in some detail with the automatic flight control system. We will see how an automatic flight control actuator receives signals which are then converted to movement of the flight controls. The secondary flight control system that we have selected is a typical speed brake system. From the information presented here, you should be able to troubleshoot these systems for specific malfunctions.

644. Specify operational features of the flight control system.

Flight Control Systems Operation. Control of the aircraft in flight is accomplished manually, electrically, and automatically. Notice in figure 4-12 that the lateral controls in the left wing are powered by PC–1 (Primary Control) and utility hydraulic power. Lateral controls in the right wing are powered by PC–2 and utility hydraulic pressure.

Manual control. Lateral movement of the control stick, figure 4-12, is transmitted mechanically by push-pull rods, through a walking beam bellcrank, to the spoiler servo valves and aileron control valves. The spoiler servo valves and aileron control valves allow hydraulic pressure to simultaneously move the spoilers and ailerons. The aileron control valves and spoiler servo valves meter hydraulic

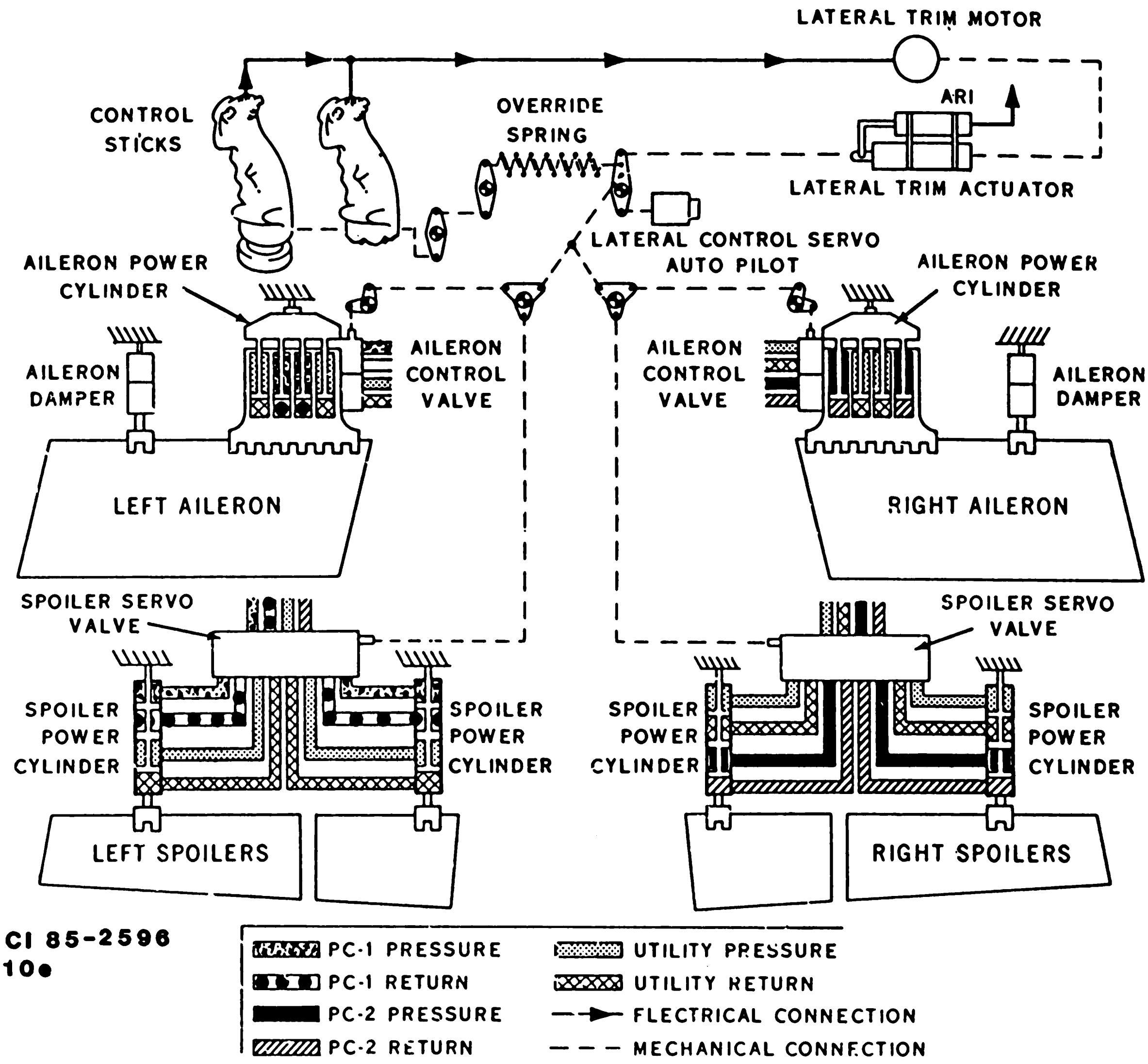

Figure 4–12. Aileron control system.

fluid to the power cylinders in proportion to mechanical displacement. An override spring, figure 4-12, is incorporated into the left and right push-pull rod systems. If one side becomes jammed, the override spring deflects under force, allowing operation of the other lateral control surfaces. A self-serviced aileron damper serves as an upstop and dampens aileron flutter.

Electrical trim. The feel trim system is composed of a trim switch, a rotary power unit, flexible drive shafts and a jackscrew actuator. When the trim switch is energized, the rotary power unit and flexible drive shafts position the screwjack actuator. As the screwjack actuator extends and retracts, the lateral controls are repositioned, and the control stick follows the trim movements. Lateral control artificial feel is provided by double-action spring cartridges connected in tandem with the screwjack actuators. When the control stick is moved from NEUTRAL, the springs are compressed. The farther the control stick is moved from NEUTRAL, the greater the force required to compress the springs. The spring cartridges return the control stick to NEUTRAL when the force on the control stick is removed.

Automatic flight control systems. The automatic flight control system (AFCS) is an electrohydraulic system that consists of a lateral control servoactuator, shown just to the right of the overriding spring in figure 4-12. The lateral control servoactuator transfers the electrical signals into mechanical motion to operate the flight control surfaces. To see how this is done, refer to figure 4-13. The black arrow indicates that the schematic at the lower left is actually contained within the outline of the servo at the upper right. Note that with the solenoid shutoff and bypass valve deenergized, pressure is blocked off at the valve; and all sides of the piston rod, centering and locking mechanism, secondary valve, and flapper (servo) valve are ported to return. This permits the spring load of the centering and locking mechanism to extend the locking ram which prevents the hydraulic servo from operating.

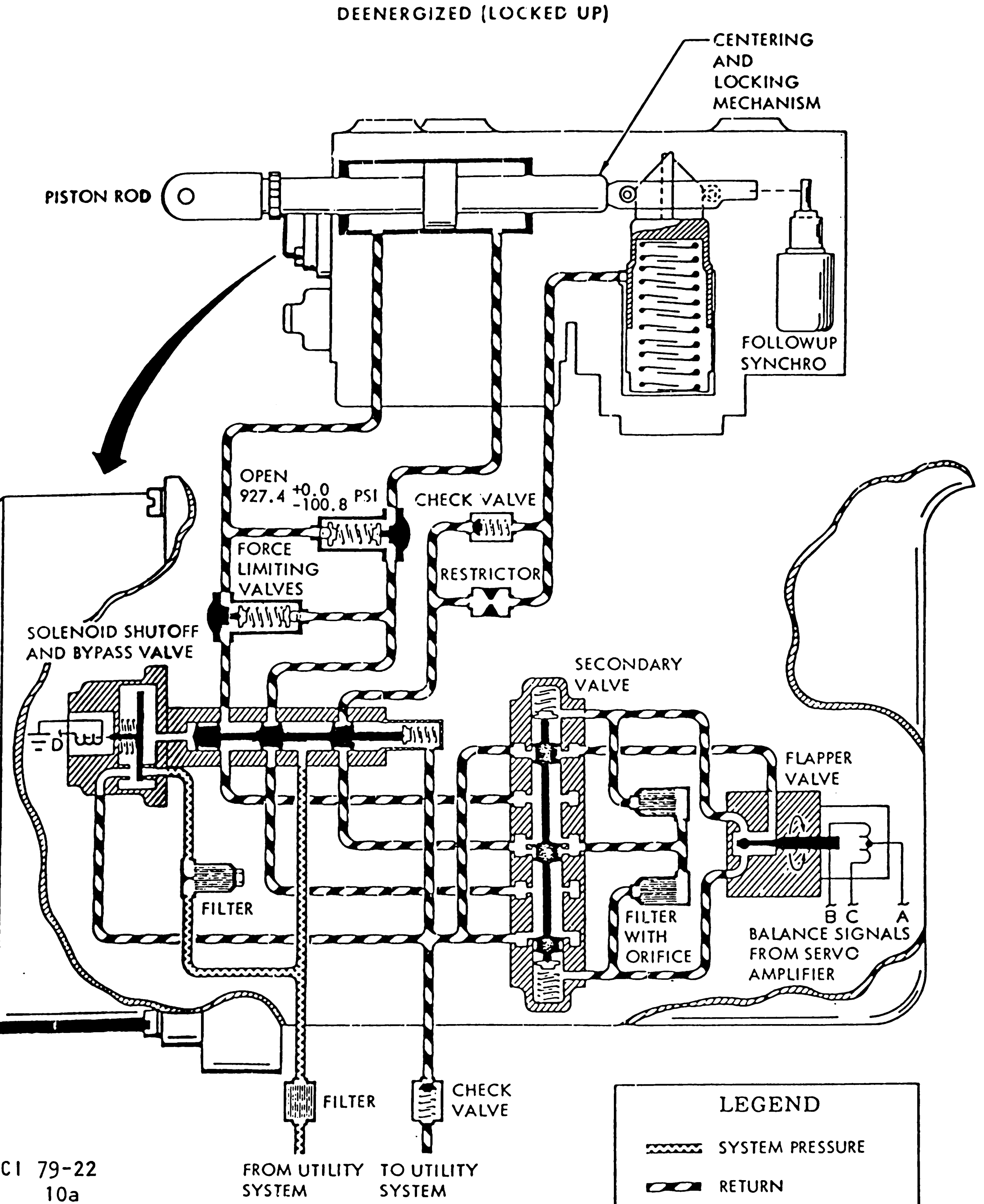

Figure 4-13. Lateral control servo actuator (deenergized).

Figure 4-14 shows the changes that take place when AFCS is engaged and there is a signal applied to the flapper valve. When AFCS is energized, power is applied to the solenoid shutoff and bypass valve. This causes the metal diaphragm to move, opening the pressure port and closing the return port of the valve. Opening the pressure port applies pressure to the centering valve. The pressure at the centering and locking mechanism compresses the spring and unlocks the piston rod assembly. Prior to application of a signal from the servoamplifier, the secondary valve and flapper valve are in the position shown in figure 4-13. However, since pressure is now applied to the secondary valve, pressure divides and is ported through the two filters (labeled "with orifice" in fig. 4-13) to the flapper valve. With no signal, the flapper valve is in the centered position and pressure bleeds to return. When a signal is applied from the servoamplifier, the flapper moves to one side, as shown in figure 4-14. This increases pressure on one side of the valve. Since this is also the pressure at one end of the spool of the secondary valve (the bottom of the valve in fig. 4-14), the secondary valve feeds load pressure through the solenoid shutoff and bypass valve to operate the piston rod. The piston rod operates the push rod of the flight control system and changes the aircraft attitude.

The follow-up synchro, attached to the piston rod, sends signals to the servoamplifier which indicate the piston displacement.

The aileron-rudder interconnect (ARI) system causes rudder displacement proportional to aileron displacement to provide coordinated turns at low airspeeds. When the system is engaged, the ARI actuator is allowed to move the control linkage (if aileron displacement is present) and cause rudder displacement.

Stabilator operation. When the control stick is moved longitudinally, the motion is transmitted by push-pull rods to a bellcrank. Motion is then transmitted by a cable assembly to another push-pull rod set. The second push-pull rod set actuates the stabilator control valve, figure 4-15, which meters hydraulic fluid to the power cylinder. Hydraulic pressure to the stabilator power cylinder is supplied by both power control hydraulic systems. If one system fails, the remaining system provides adequate control response.

A hydraulic AFCS servo, figure 4-15, is integrated into the stabilator control valve. This servo positions the dual servo valve in the same manner as a control stick inputs. As a result, when the autopilot signals for a pitch altitude change, the control stick follows the movement.

Artificial feel is provided by a dynamic ram air bellows, figure 4-15, acting through a bob weight and through a variable bellcrank on the trim actuator. When the aircraft is in trim, the ram air force on the bellows is balanced by the bob weight. The bob weight increases stick forces so as to compensate for increase in G forces. As the aircraft increases or decreases in airspeed, the pressure on the bellows changes. This causes the bellows bob weight assembly to become off balance. The off-balance condition is then transmitted through the trim actuator, control cables, and push-pull rods back to the control stick. Then by actuating the trim switch, the stabilator trim actuator moves, balancing the forces between the bellows and the bob weight, thereby eliminating force on the control stick. An override spring cartridge allows the feel and trim portion of the stabilator control system to be bypassed in the event of noseup trim malfunction.

Rudder operation. When the rudder pedals are moved, the motion is transmitted by the push-pull rods, bellcranks, and cable assemblies to the rudder servo valve to the rudder power control cylinder, figure 4-16. The servo valve meters utility system hydraulic fluid to the power control cylinder, which positions the rudder. Should hydraulic pressure fail, the power control cylinder acts as a solid link in the control system, allowing the pilot partial rudder deflection. A bypass valve in the power control cylinder opens when hydraulic pressure is lost, allowing fluid to pass from one side of the cylinder piston to the other. Total amount of rudder deflection is then a function of air loads on the rudder. A rudder damper is incorporated in the rudder power control cylinder to dampen rudder flutter during manual and AFCS operation.

Artificial feel is supplied to the rudder pedals by a feel trim system. A rudder trim actuator, figure 4-16, acts against the rudder feel cylinder, causing artificial feel. At low airspeeds, the rudder feel selector valve is deenergized by the rudder airspeed pressure switch. This allows utility hydraulic pressure to act on both sides of the feel cylinder piston, thereby decreasing feel force. At high airspeeds, the feel selector valve is energized, allowing utility hydraulic pressure to act on the rod end side of the feel cylinder piston and thereby increasing feel force.

Rudder trim control is accomplished by the rudder trim switch, figure 4-16. This switch energizes the rudder trim actuator or motor to either extend or retract the actuator. As the actuator extends or retracts, the feel trim bellcrank moves the walking beam bellcrank, causing the rudder power control cylinder to deflect the rudder in proportion to the feel trim actuator.

Exercises (644):

1. Lateral control of the aircraft is accomplished by what two means?

2. What is the purpose of the override spring in the left and right aileron push-pull rod system?

3. Does the control stick follow trim movement as the ailerons are repositioned?

4. Should the utility hydraulic system fail to the rudder, is there a backup means of control?

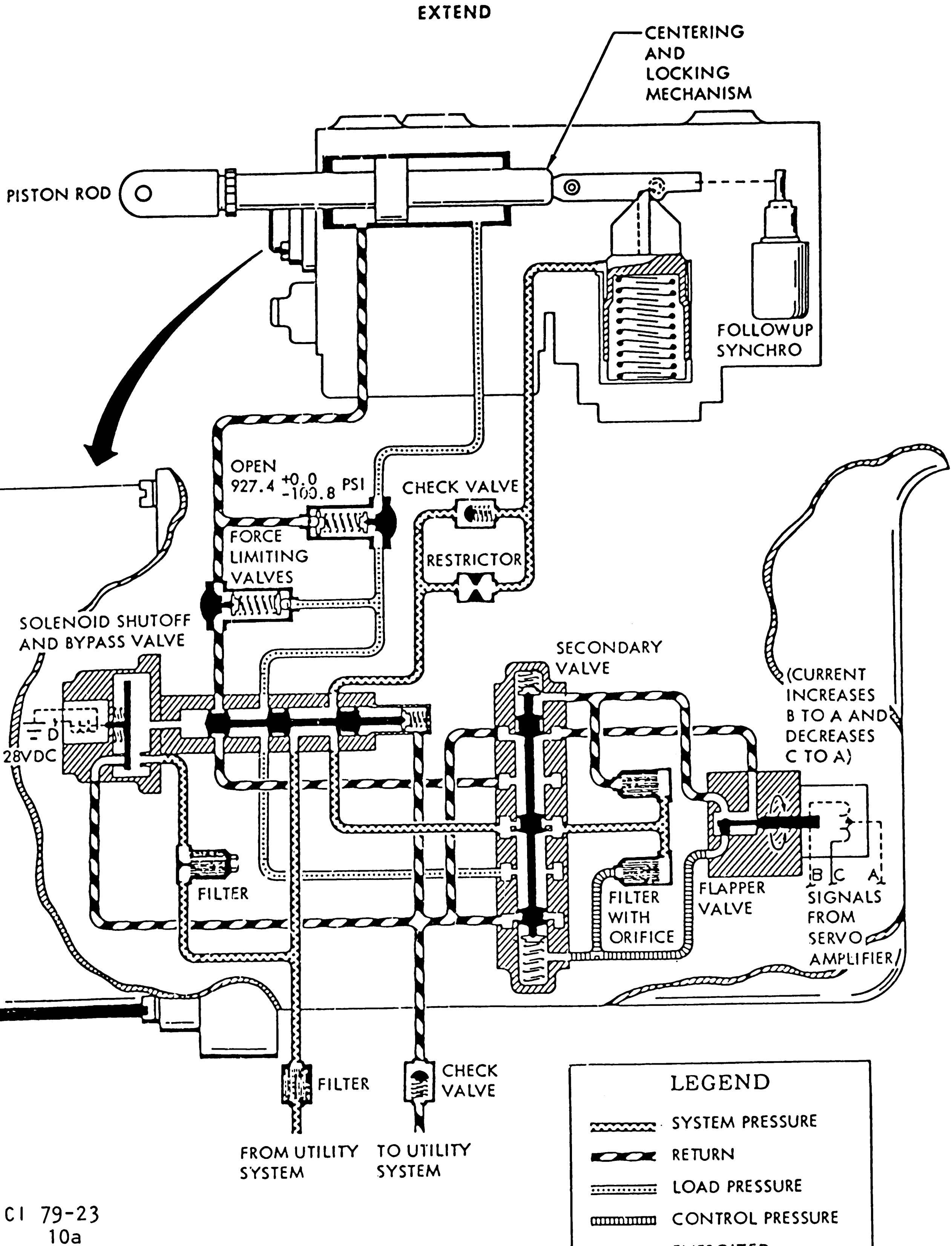

Figure 4–14. Lateral control servo actuator (energized).

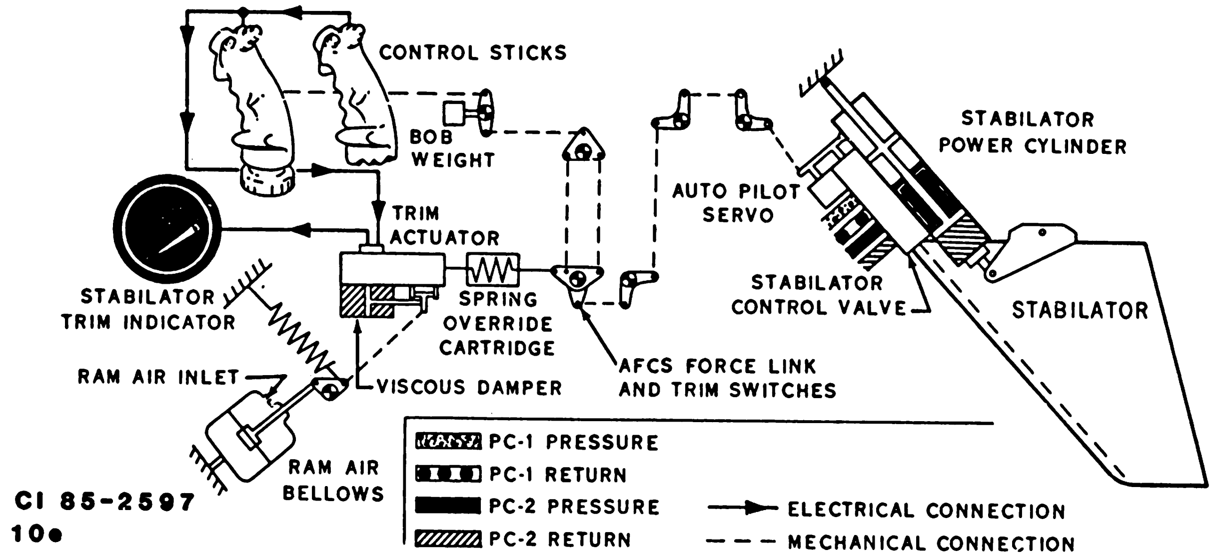

Figure 4–15. Stabilator control system.

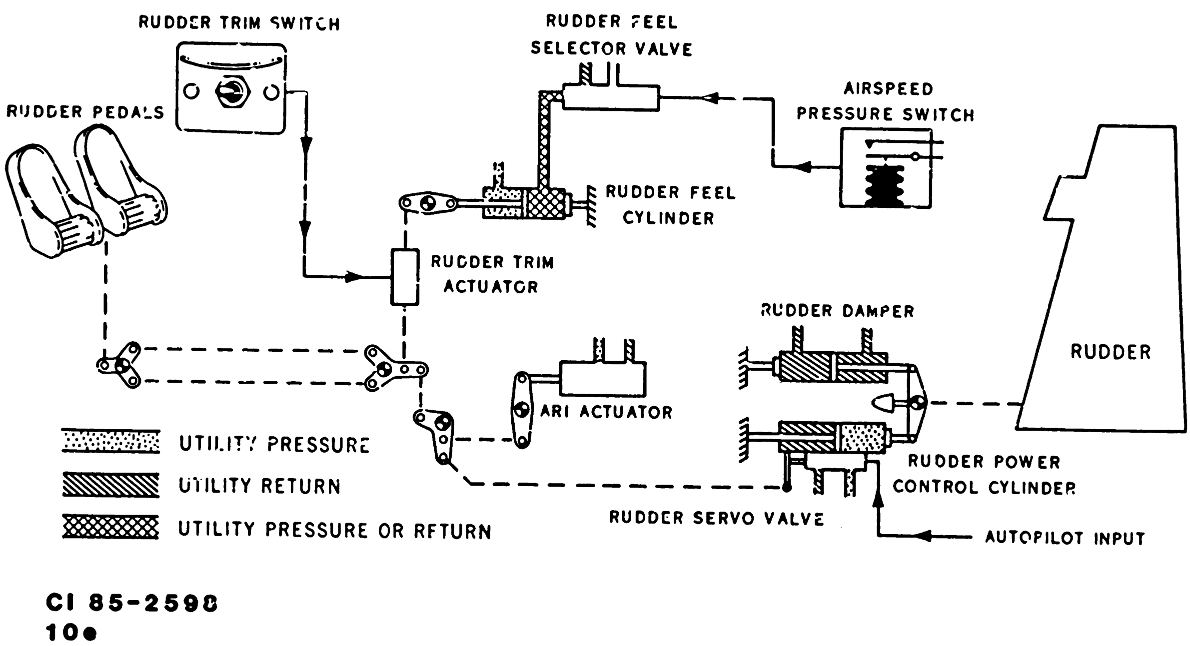

Figure 4–16. Rudder control system.

5. Is there more rudder feel force at high airspeed than at low? Why?

6. What valves in the lateral control system meter hydraulic fluid to the power cylinders in proportion to mechanical displacement?

7. State the two simultaneous modes of operation of the AFC system.

8. What provides lateral control artificial feel?

9. What is the purpose of the ARI system?

10. What provides artificial feel in the stabilator system?

11. In the stabilator system, what is the purpose of the stabilator control valve?

12. What is the purpose of the override spring cartridge in the stabilator system?

4-4. Secondary Flight Controls

In addition to primary flight controls, some aircraft are equipped with auxiliary (secondary) flight controls. These are mostly lift and drag devices used to give the aircraft a shorter landing and takeoff roll, to allow it to take off with greater loads, or to create additional drag to control the aircraft flight. One of the most common types of auxiliary flight controls is the wing flaps.

645. Trace the fluid flow through the flap system and specify how the asymmetry brakes are applied.

Wing Flap System Operation. The wing flap system shown in figure 4-17 shows two Fowler-type flaps that are hydraulically operated by jackscrews. This control system raises and lowers the flaps according to the movement of a control lever in the flight station. Normal operation is by utility hydraulic system pressure. Emergency operation is by a manually operated drive assembly. During normal operation the flap lever (fig. 4-17) provides manual control of wing flap movement. As the lever is moved between the UP and DOWN positions, it energizes a solenoid-operated wing flap selector valve. Then pressure is directed to the up or down port of the flap motor. In turn, the motor drives the torque shafts and the jackscrews are rotated in the direction necessary to raise or lower the flaps.

A hydraulic disc flap brake (fig. 4-17) is automatically applied when movement of the flap lever and movement of the followup switch assembly in the control unit has stopped. This brake holds the flaps in position. The asymmetry brakes (fig. 4-17) mounted on the ends of the torque shaft hold the flaps in position at the instant the right and left shaft ends reach a dangerous unsynchronized condition. Asymmetric sensing switches are part of each asymmetry brake. Out-of-symmetry closes the electrical circuit through a switch in the LH brake and a switch in the RH brake. As the circuit energizes, the emergency flap brake valve repositions to divert fluid from the flap motor to the asymmetry brakes. If the flaps are not stopped, it could cause a violent roll of the aircraft. Now, the flaps cannot be operated until the electrical power is disconnected from the emergency flap brake valve, and the manual release latch on the valve is actuated. With power disconnected and the latch pulled, the emergency flap brake valve returns to the normal position. If hydraulic pressure is lost, the flaps are operated manually.

Exercises (645):

1. What causes the asymmetry brake system to be applied?

2. How are the flaps operated in emergency?

3. What holds the flaps in the desired position?

4. What hydraulic valve will the flap lever energize?

5. To what component is hydraulic pressure from the flap selector valve directed?

646. Trace the fluid flow through the flap system and specify the procedures for raising and lowering the flaps.

Raising and Lowering Flaps. Normal operation of the flap system, as shown in Foldout 9, is controlled by a switch in the forward cockpit. This switch has three positions—UP, 1/2, and DN. When the switch is placed in the 1/2 DOWN position, the selector valve allows utility hydraulic pressure to flow through the shuttle valves and

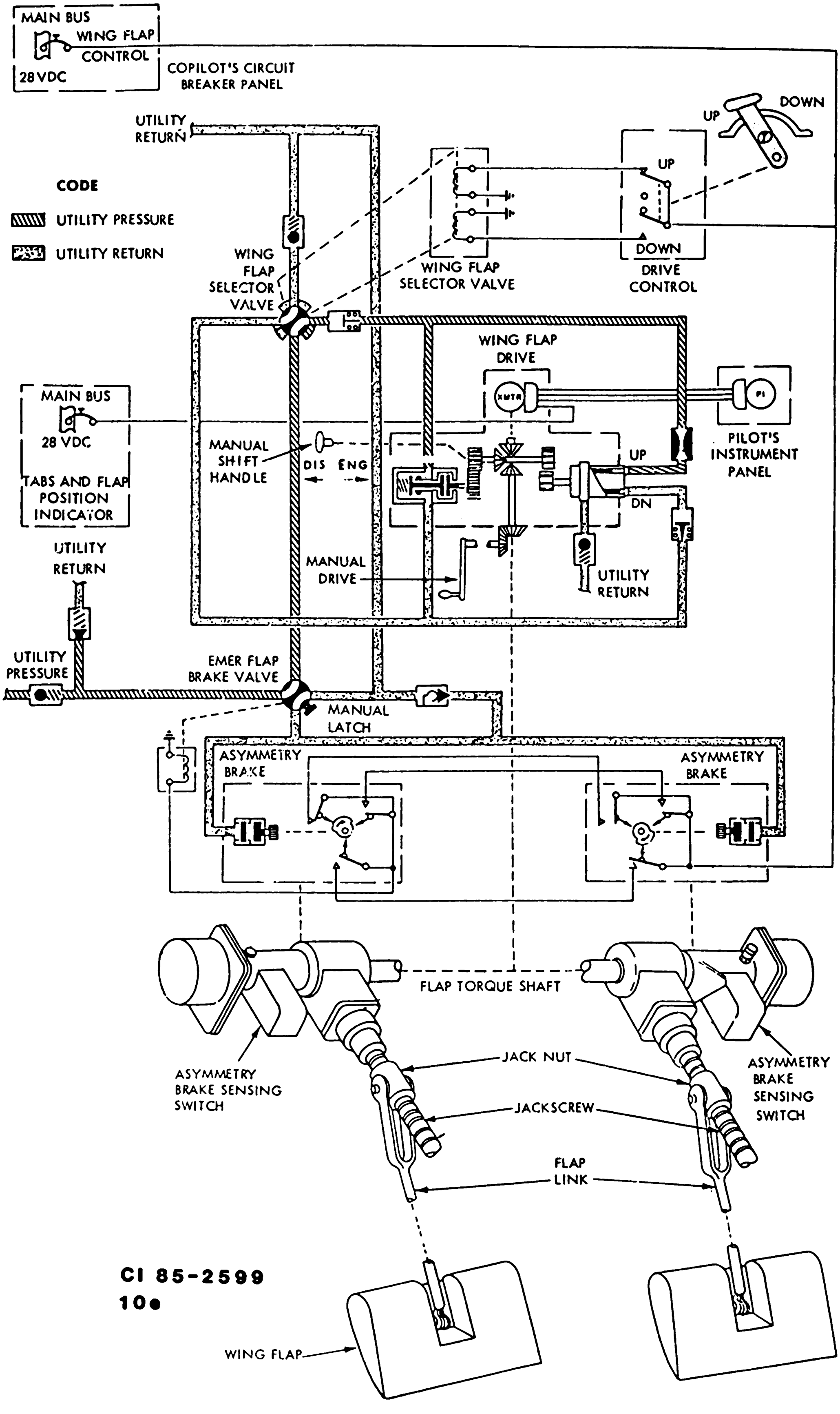

Figure 4–17. Wing flap system.

into the down side of the leading edge (LE) flap actuating cylinders. In turn, the leading edge flaps move to the FULL DOWN position. At the same time, hydraulic fluid flows through the flow divider and into the trailing edge (TE) actuating cylinder, moving the TE flaps to the 1/2 DOWN position.

Movement of the flap control switch to DN allows hydraulic fluid to flow through the selector valve through the flow divider and into the down sides of the TE flap actuating cylinder. In turn, the TE flaps move from 1/2 to the FULL DOWN position.

Movement of the flap control switch to UP allows hydraulic fluid to flow through the selector valve through the flow divider and to the LE and TE flap actuating cylinders. In turn, the flaps return to the FULL UP position. When the TE flaps begin to move up, the UP indicator light will come on. When the flaps are FULL UP, the electrical control circuits and the solenoids on both selector valves are deenergized.

In case of electrical or hydraulic power failure, emergency flap extension is provided by high-pressure air from an air bottle charged to 3000 psi. When the flap control handle (forward or aft cockpit) is pulled, the piston inside the air selector valve is shifted. This allows high-pressure air to flow through a separate set of lines to the down side of the actuating cylinders. As the LE and TE flaps extend, the dump valve opens to dump return hydraulic fluid overboard.

The flap blowup switch will automatically raise the flaps if the airspeed exceeds a certain amount.

Exercises (646):

1. When the switch is placed in the 1/2 position, through what components will hydraulic fluid flow to lower the TE flaps to the 1/2 DOWN position?

2. What happens to hydraulic fluid when the dump valve is positioned during emergency operation?

3. What slows the speed of the leading edge flaps?

4. What position will the flaps move to when the emergency system is used and the flap selector switch is placed in the down position?

5. To what components will hydraulic fluid from selector valve 2 flow?

6. When the flap control switch is moved to the UP position, through what components will hydraulic fluid flow to raise the flaps?

4-5. Flight Control System Maintenance

Maintenance is the name of the game; as pneudraulic systems mechanics, this is what should concern you. Flight control systems maintenance includes operational checks, removal and replacement of components, inspection of the system and components, and bench checking and repairing the flight control system components. Because the coverage of the multitude of aircraft and components associated with flight control systems is beyond the scope of this CDC, the information presented on these areas in this section will be general in nature. It is advisable to follow TO procedures for performing maintenance on specific aircraft flight control systems.

647. Specify the purpose of inspecting specific items of the flight control systems and the general equipment, procedures, and safety precautions associated with an operational check.

Flight Control System Inspection. Begin the inspection with the controls in the cockpit, because all controls are connected there. Remove all access panels that cover any part of the control system. Go over the full length of the cable to see if an excessive number of wires are broken. Check the cable carefully where it passes over pulleys or through fairleads, since these are points where breaks most often occur.

Carefully inspect for corrosion and badly worn spots. Adjust the cable tension if necessary by adjusting at turnbuckles. Check the turnbuckles for proper safetying, for number of exposed terminal threads, and for cracks in the barrel. Check the pulleys for cracks and wear. If there is any indication of weakness of any kind, replace the pulley or the mount, or both.

Examine the fairleads, pressure seals, and guides for binding, wear, and corrosion. Check all units for cracks and bends. Check the hinges connecting the control surfaces to the aircraft. They should operate freely but should never be loose.

Inspect the hydraulic components for security, proper installation, and leakage. Many hydraulic components have allowable leakage rates, so be sure to check the applicable TO for the leakage rate. In the past, hydraulic units have been replaced simply because they had a drop of fluid hanging from a fitting. The way to determine if a component is leaking is to perform an operational check.

Flight Control Systems Operational Checks. Briefly, the operational check is checking to see that the control surface goes to the right position when you move the control device in the cockpit. It also checks for leaks, binding, security or any other malfunction. This check includes the indicator and lights used to give the pilot an indication of the position of the control surface. For specific

inspection items and tolerances, always refer to the applicable -6 technical order.

Equipment. Selection of equipment for performing operational checks of flight controls depends, of course, upon the type aircraft. Generally speaking though, it consists of a hydraulic test stand, a generator set, or suitable substitute.

Procedures. Before performing an operational check, make sure the control system rigging is in good condition. Next install a template.

Templates are patterns or guides used, among other things, to measure the travel of control surfaces on aircraft. Usually made of metal, they are inserted between the movable and a stationary surface, as illustrated in figure 4-18. The template is made so that when inserted, it will fit snugly on the stationary surface with a zero mark that is aligned with the neutral position of the movable surface. Sometimes, the template is clamped in this position if it is not possible to secure a snug fit otherwise.

The face of the template is marked off in degrees from both sides of the ZERO position. When the template is inserted or fitted in place, travel of the control surface in both directions can be measured by moving the surface to its extreme limit of travel, reading from zero to the right (or left), then to the opposite extreme, and by reading and recording the figures on the template at each extreme. Most templates are made for a particular aircraft; for this reason, you must use care in selecting the correct template for a particular job. The -2 technical order for the aircraft concerned contains the correct surface travel in both degrees and inches.

Safety. Safety precautions must be observed at all times around the aircraft, and it is never more necessary than while you are operating or working around the flight controls. Never operate a control surface unless you have first cleared it. Never work on a control unless you have first immobilized it. There have been several persons killed and many more injured because of the failure to properly clear a flight control before actuating it. There have been accidents due to people having their hands in the control linkages when movement occurs.

Exercises (647):

1. What does the operational check of the flight controls normally consist of?

2. What are the two main pieces of support equipment you will be using to operationally check flight controls?

3. Other than determining their conditions, which safety precaution should you observe before moving the controls?

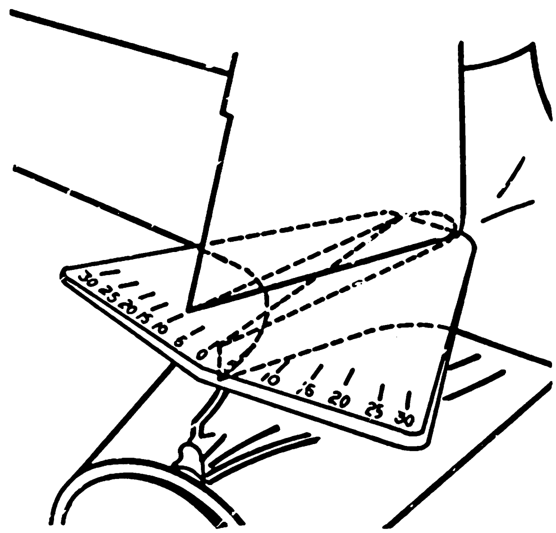

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Figure 4-18. Flight control template.

4. Why must the cable be inspected carefully where it passes over pulleys or through fairleads?

5. What would be done if weakness was detected in a pulley on inspection?

6. Why is a template used during an operational check?

7. Why must the applicable aircraft TO be checked for component fluid leakage rates?

8. Can any template be used on any aircraft? Explain your answer.

648. Name the source for instructions for removal and installation of flight control components, and specify procedures applicable to the removal, installation, bench check, and repair of flight control system components.

Flight Control Removal and Installation. From time to time, units in the flight control system must be removed,

replaced, adjusted, operationally checked, cleaned, or lubricated. The applicable organizational maintenance manual lists specific procedures that must be followed.

Because of the mechanical linkage involved, normal use will require some adjustments. When inspections indicate the need, it becomes necessary to rig and adjust the mechanical linkage in the flight control system.

Removal procedures. Removal procedures differ from component to component in the flight control system, so we do not go into a detailed explanation of removal. However, the details of removal and installation have some similarities. These are:

- Assemble the tools and equipment for removal.
- Insure that hydraulic and electrical power are removed from the aircraft.
- Relieve hydraulic pressure.
- Disconnect hydraulic lines or hoses from the component being removed.
- When hydraulic lines or hoses are disconnected, tag them while disconnecting them to prevent cross-connection during installation.
- Cap the lines and hoses to prevent contamination from entering the system.
- Disconnect mechanical linkage to the control valve.
- Remove mount bolts.

Bench check and repair of flight control components. Because the flight control components are so critical, most of the power control cylinders cannot be bench checked or repaired properly at base level. You can check them for external leakage, but this, of course, will depend on –6 technical order. Simple shutoff valves, fittings, restrictions, etc., can be bench checked and repaired within the capabilities of the shop and –6 limitations.

Installation procedures. Installation procedures, like removal, vary from component to component. The most important single point to remember when installing components is to read each step of the technical order individually. Then insure the step is complied with. This is especially true concerning the NOTES, CAUTIONS, and WARNINGS. Though the procedures vary, some main points remain fairly constant.

The installation will usually require that you perform an inspection of the units to which you will be attaching the serviceable component. Check for proper adjustment of the hydraulic cylinder and/or rigging. You must assure proper torque has been applied. Lubricate the specified points and, finally, check for proper operation.

Safety precaution. Safety must never be ignored while working around aircraft. This is one very important aspect of flight control maintenance that cannot be overstressed. Always assure the controls are clear before applying hydraulic pressure to the aircraft to prevent injury to personnel.

Exercises (648):

1. Where can you locate the procedures for removing flight control system components?

2. What is the final step in the installation procedure?

3. Why should hydraulic lines be tagged before disconnecting them from a unit?

4. What determines whether simple shutoff valves and restrictors can be bench checked and repaired by the pneudraulic shop?

5. What is the most important single point to remember when installing a flight control system component?

6. What can be done during removal of a component to insure that dust or dirt will not enter the hydraulic system?

649. Given hypothetical situations pertaining to the flight control systems, solve the problems by stating applicable procedures or specific trouble.

Troubleshooting Flight Controls. One of the prime responsibilities of a pneudraulic specialist is troubleshooting the flight control systems. Although most of the problems that you will have with the flight controls will be through leakage (internal or external), you may be called upon to rig and/or adjust mechanical linkage also. To do this you must know how the system should function and as much as possible of the construction and operation of the units involved. As we have mentioned previously, it is always wise for you to have schematic drawings of the system, no matter how well you may know the system. This keeps you from overlooking simple but obvious components that may have malfunctioned. In this objective, we will troubleshoot the lateral control and speed brake systems previously discussed in this chapter. We begin first with the lateral control system.

Lateral control system. As stated earlier, most of the problems that you will have on this system will be through external leakage. Another problem is with air. Air can cause a multitude of problems. Since the flight controls are actuated by actuating cylinders, which are controlled by control valves, it doesn't leave much for troubleshooting. Some of the areas that do malfunction are in the mechanical linkage electrical trim and automatic flight control systems. Let's look at some of these malfunctions.

a. Mechanical malfunctions. Linkage out of adjustment, too tight or too loose will cause many unusual problems. For instance, if the linkage is out of rig, it could cause the flight controls to move farther one way or another. If the linkage is too tight it could make the control stick stiff to

operate or even to bind. If the linkage is too loose or worn, it will cause the controls to be sloppy.

b. Electrical trim malfunctions. One of the malfunctions that may occur with the trim system is that there is no left or right trim. This problem could be caused by several things in the electrical system. Notice in figure 4-12 that the trim motor can be positioned by either control stick. To determine if the control switches are functioning properly, use one and then the other. If trim works when one stick switch is actuated but not the other, you can suspect that one of the control stick switches is bad. If the trim still does not function, then move on to the next component. The next item in line is the trim motor. To check the trim motor, disconnect the flex shafts from the motor to the lateral trim actuator. Now operate the trim switches in the cockpit once more. Does the trim motor work? If not, the trim motor is malfunctioning. If it works properly that leaves the flex shafts or the lateral trim actuator. NOTE: Improper torque on flex shaft coupling nuts will cause flext shaft to bind and create trim problems.

Automatic flight control system. The lateral control servoactuator used in the autopilot system is attached to the mechanical input to the lateral control system. Although this unit is an electrohydraulic actuator, it will more than likely be troubleshot by the automatic flight control system personnel. To do this the AFSC people will use a test control box similar to the one shown in figure 4-19. This test box is used to test the various circuits and units built into the servocontrol valve. On many occasions, though, the test boxes have malfunctioned or have been calibrated improperly. This lead to a component in the automatic flight control system being changed, when it was totally unnecessary. Insist that the test be performed again, preferably with another test box, before changing the unit.

Speed brake system. The speed brake system, as shown in foldout 10, has only three hydraulic components (selector valve, flow divider, and actuating cylinder). Even so, it will take some thought on your part to troubleshoot this simple system. Some of the things that can happen besides leakage are these: Speed brakes will not extend, aircraft

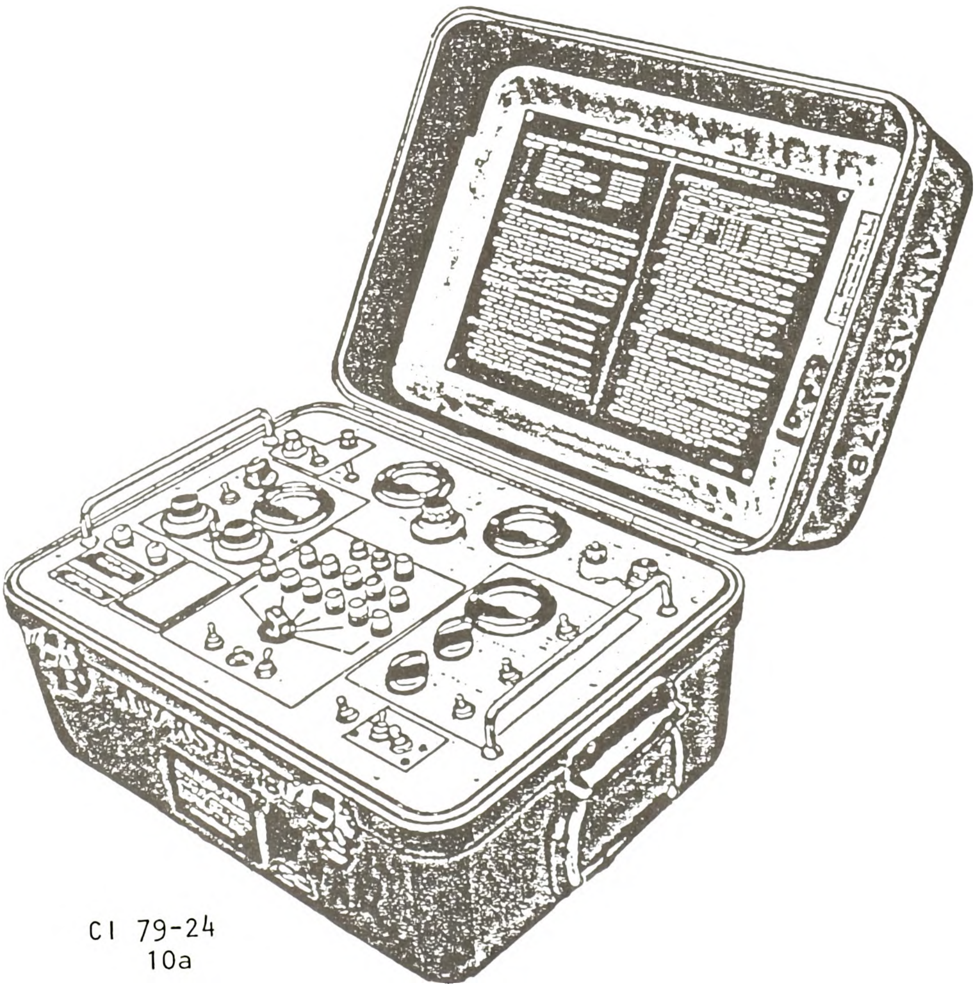


Figure 4–19. AFCS test box.

rolls during operation of speed brakes, or the warning light malfunctions. These are just a few of the common malfunctions that may arise. Let's look at some of these to see how we can isolate some of the malfunctions and possibly determine what is causing these troubles to take place.

The electrical system consists of a circuit breaker, control switch, and relay. If the speed brakes will not extend, as an example, check to see if hydraulic pressure and electrical power are available to the selector valve. If power is available at the selector valve, you can suspect that it or something in the hydraulic system is bad. If power is not available, possibly the control switch or wiring is defective.

If the aircraft rolls during extension or retraction of the speed brakes, you can suspect the flow divider as being bad. As an example suppose the speed brakes are placed to the out position but the left speed brake moves slower than the right. If the flow divider does not compensate for this difference, the aircraft would have a tendency to roll, since one speed brake will be farther out than the other.

Another malfunction that you may have with this particular system is that the warning light will not come on or go out when it is supposed to. As an example, when the speed brake switch is placed to the OUT position and the speed brakes extend, the warning light should come on. If the speed brake warning light does not come on, then it could be that the circuit breaker has popped, light is burned out, wiring is defective, or both position switches are bad. It is highly improbable that both position switches are defective, so you should suspect one of the other items first.

Let's look at another example. What if the light stayed on when the speed brakes were retracted? This could be caused by defective wiring or a defective position switch. Since either switch completes the circuit to the warning light, you must determine which switch is bad. Improper adjustment of the brake panels or switch can cause the light to stay on.

Exercises (649):

1. What must be used to troubleshoot the automatic flight control system?

2. During a check of the flight control system, you find excessive play in the control stick. What could cause this malfunction?

3. During electrical trim of the lateral control system, the trim would not work when the trim switch was operated in the front cockpit. What should be done next to determine what is wrong in the system?

Use foldout 10 when answering the following questions.

4. Specify what malfunctioned, if anything, when the speed brake warning light came on when the speed brake control switch was placed in the OUT position and the aircraft rolled to the left?

5. Determine which solenoid(s) on the speed brake control valve have malfunctioned when the speed brake control switch is placed to the OUT position and the speed brake remains stationary?

4-6. Bench Check and Repair of Flight Control Components

Maintenance of flight control system components is generally beyond the capability of intermediate and organizational maintenance level activities. Removal of hydraulic components and associated linkages on the power actuators will destroy critical adjustments which require the use of special tooling, jigs, and other equipment available only at depot level maintenance facilities. For this reason, we will not discuss the bench check and repair of hydraulic power control cylinders. Instead, we will only discuss the testing of a typical power control cylinder. Then we will consider a simple speed brake actuator that can be bench checked and repaired at most pneudraulic shops.

650. State specified conditions/actions involved in bench checking a power control cylinder used in the flight control system.

Power Control Cylinder Testing. The following instructions should enable you to determine whether the hydraulic power control cylinder is operating within acceptable standards. Equipment required for testing the power control cylinder includes a pressure gage capable of indicating hydraulic pressures from 0 to 4500 psi, a selector valve for leakage measurement, a metering valve to control flow, and a hydraulic test stand. Set up the test equipment for checking the power control cylinder as shown in figure 4-20. Bleed all air from the servo cylinder by applying 5 psi on the pressure port and operating the crank (fig. 4-21) back and forth. Then operate the crank to one extreme position and hold for a minimum of 2 minutes. Reduce pressure to 0; operate the crank several times, and repeat the operation with crank held in the opposite extreme position. There must be no evidence of external leakage. Using the metering valve in the return line (fig. 4-20), reduce the flow until 4500 psi is indicated on the pressure gage. Operate the crank to one extreme position and hold for a minimum of 2 minutes. Reduce the pressure to 0, operate the crank several times, and repeat the operation with the crank held in the opposite extreme position. There must be no evidence of external leakage, permanent deformation, or rupture of parts.

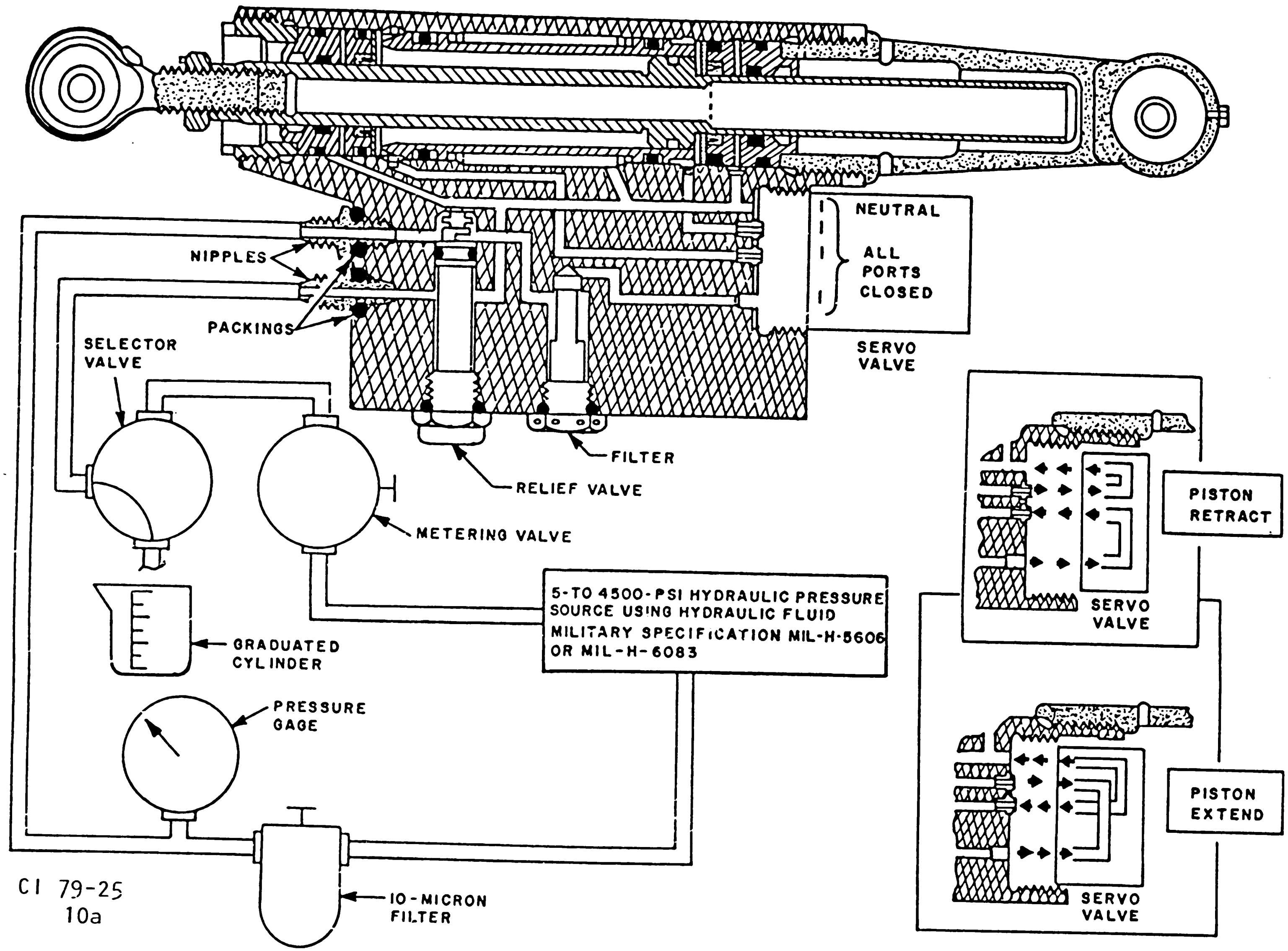


Figure 4–20. Servo control cylinder test set-up.

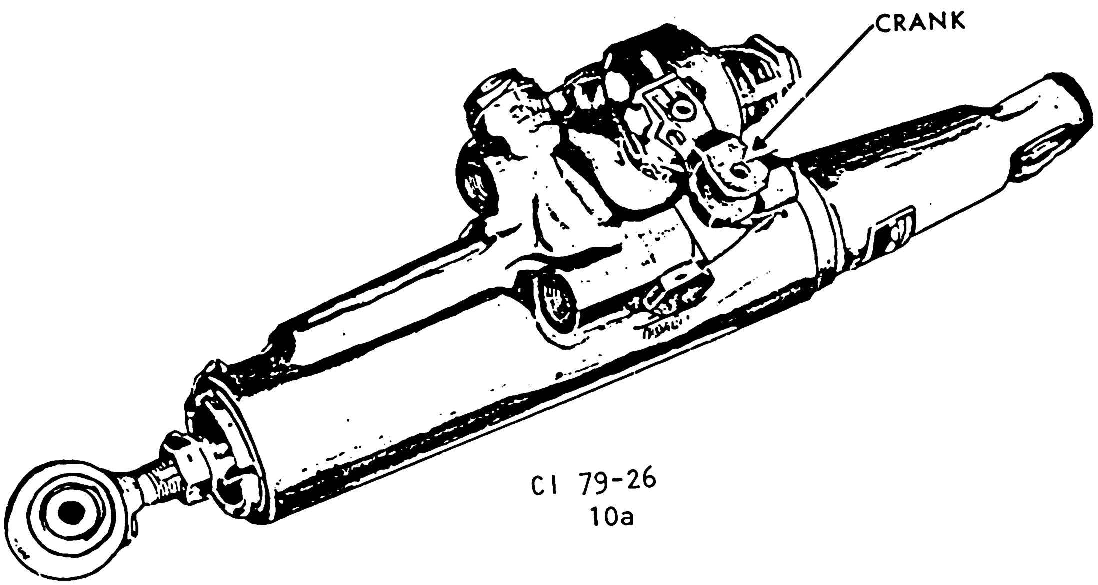


Figure 4–21. Servo control cylinder.

With the return port closed, apply 1500 psi to the pressure port for a minimum of 2 minutes. There must be no evidence of external leakage, permanent deformation, or rupture of parts. Now apply 3000 psi to the port. Move the crank to one extreme position and hold. After the first 2 minutes, collect leakage from the return port in a graduated container. Internal leakage must not exceed specified amounts listed in the TO. Move the crank to the opposite extreme position and repeat.

With the selector valve open to the metering valve, and the metering valve open, apply 3000 psi to the pressure port. Move the crank to one extreme position and hold for 3 minutes. After the first 2 minutes, open the selector valve to the graduated cylinder. Internal leakage must not exceed specified TO limits. Now with the crank in the opposite position repeat the procedure.

With 3000 psi applied to the pressure port, adjust the servo valve crank to a center position so that the piston remains still. This is done by adjusting the crank stops on either side of the crank. This position is called hydraulic neutral. Now position the crank to retract the piston and measure the force required to move the crank. It too must be within specified TO limits.

With the return port open, apply 1000 psi to the pressure port. Position the servo valve crank to fully extend the piston rod. Rapidly move the crank in the opposite direction against the travel stop to fully retract the piston rod. Record the time the piston rod takes to go from the fully extended to the fully retracted position. Rapidly move the crank to the opposite direction against the travel stop to fully extend the piston rod. Record the time the piston rod takes to go from the fully retracted position to the fully extended position. Obtain the average time, for the piston rod to move through the full range of travel, using the extend and retract times. The average operating time must be within specified TO limits. Failure to meet this requirement requires the replacement of the servo valve assembly.

Perform the final checkout by placing the crank in the neutral position, apply 25 psi to the pressure port. Operate the crank in the opposite direction to both extremes several times. The piston movement must correspond to crank movement with no evidence of hesitation or binding. Open the return port and apply 3000 psi to the pressure port. Operate the crank to position the piston rod to each extreme of travel and measure the piston stroke. The stroke must be within specified limits of the TO. Reduce the hydraulic pressure to 0. Disconnect the power control cylinder from test set, drain the unit, and cap all ports.

Exercises (650):

1. While testing the servo control cylinder, the crank is positioned to hydraulic neutral but the piston continues to travel. What could be wrong?

2. What is one of the first things you should do after hooking the cylinder up and before testing the servo control cylinder?

3. How is internal leakage of the cylinder measured?

4. If the time required to extend and retract the actuator is not within specified TO limits, what must be done?

651. Specify the bench check and repair procedures to follow when troubleshooting a flight control system actuator.

Bench Check and Repair of Simple Actuator. To bench check and repair the actuator, shown in figure 4-20, requires no special tools or test equipment that could not be found in any pneudraulic shop. Disassemble the actuator in the same order as the key index numbers assigned to the exploded view in figure 4-22, with these exceptions: Do not remove the bearing (2) or grease fitting (3) from rod end (1) unless they are damaged and require replacement. After the

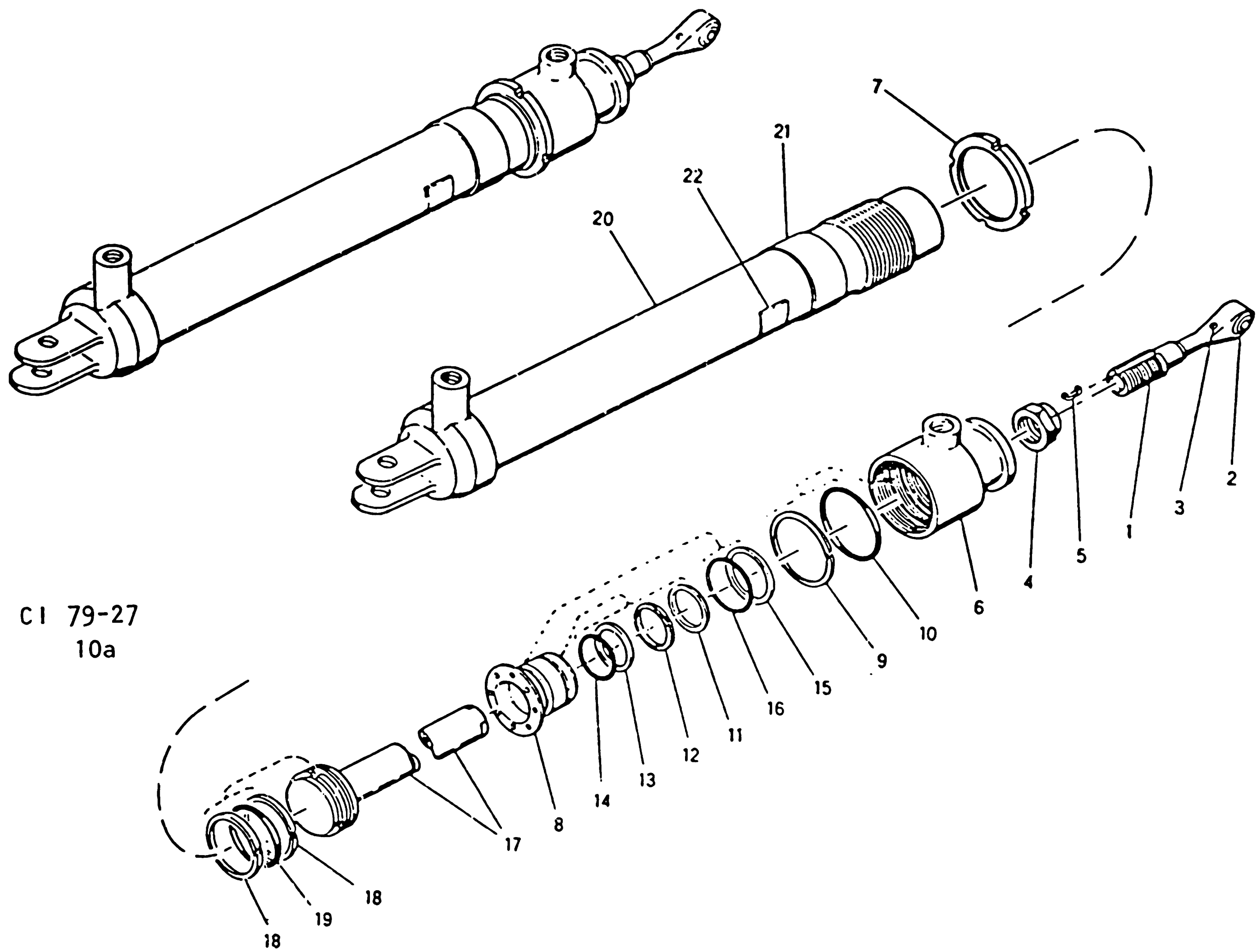


Figure 4–22. Speed brake actuator (breakdown).

actuator has been disassembled, the end cap (6) and barrel (20) should be stripped of paint. This is necessary in order to perform nondestructive testing of these parts. After stripping these parts of paint, clean all nonkitted reusable parts with cleaning solvent and dry parts thoroughly with a clean, lint-free cloth or with compressed air at 20 psig pressure maximum. After cleaning all parts, inspect them under a strong light and, preferably, using a means of magnification. (NOTE: If the inspection is not performed immediately after cleaning, apply a thin coat of preservative hydraulic fluid, MIL-H-6083 on all steel parts to prevent corrosion.) During inspection, you should check all parts for nicks, cracks, scratches and corrosion. Check all threaded parts for crossed or otherwise damaged threads. All packing grooves should be especially checked for surface defects that might cut packings during installation or cause sealing failures during operation. Polish out minor nicks and scratches on steel parts with crocus cloth and on aluminum parts with aluminum oxide abrasive cloth. All other parts that cannot meet specification in the TO should be replaced as well as all packings and back ups regardless of apparent condition. Prior to reassembly, lubricate all packings by applying a light coat of hydraulic fluid to help in reassembly.

Now reassemble all parts in reverse order of disassembly. We will go through the step-by-step procedure so that you can get a good idea of how this is done. To begin with, carefully install packings (10, 14, 16, and 19), packing retainers (9, 13, 15, and 18), scraper (11), and felt wiper (12) in their respective grooves, as shown by the dotted lines in figure 4-22. With packings and retainers installed in the bearing (8), insert the bearing into the end cap (6). Install piston (17) in barrel (20) using care not to cut or damage the packing and retainers. Thread nut (7) on to barrel (20) and screw end cap (6) onto barrel until it bottoms. Then back off the barrel a maximum of one turn to align the fluid ports of the actuator. If the bearing (2) was removed from rod end (1) during disassembly, then it will have to be reinstalled. To prevent it from coming out, it should be staked lightly in four places on each side. Now screw the rod end (1) with lock nut (4) and lock (5) into the piston rod (17). Cycle the cylinder assembly by hand to assure free travel of the piston. Now check the stroke of the piston as well as the retracted and extended length of the actuator. This measurement is made from the centerline of the rod end bearing (2) and the cylinder bearing (20) mounting holes. If the length is incorrect, then thread the rod end (1) in or out of piston (17) to establish the correct length. If the stroke is incorrect, then the barrel will have to be screwed in or out of the end cap (6) until the desired stroke is reached. (NOTE: Do not exceed the maximum of 1 turn, discussed earlier.) With the actuator adjusted correctly, tighten the lock nut (4) and safety wire to lock (5). Also tighten the nut (7) and safety wire to end cap (6). If the paint was removed to perform the nondestructive inspection, then it will have to be repainted. Before doing

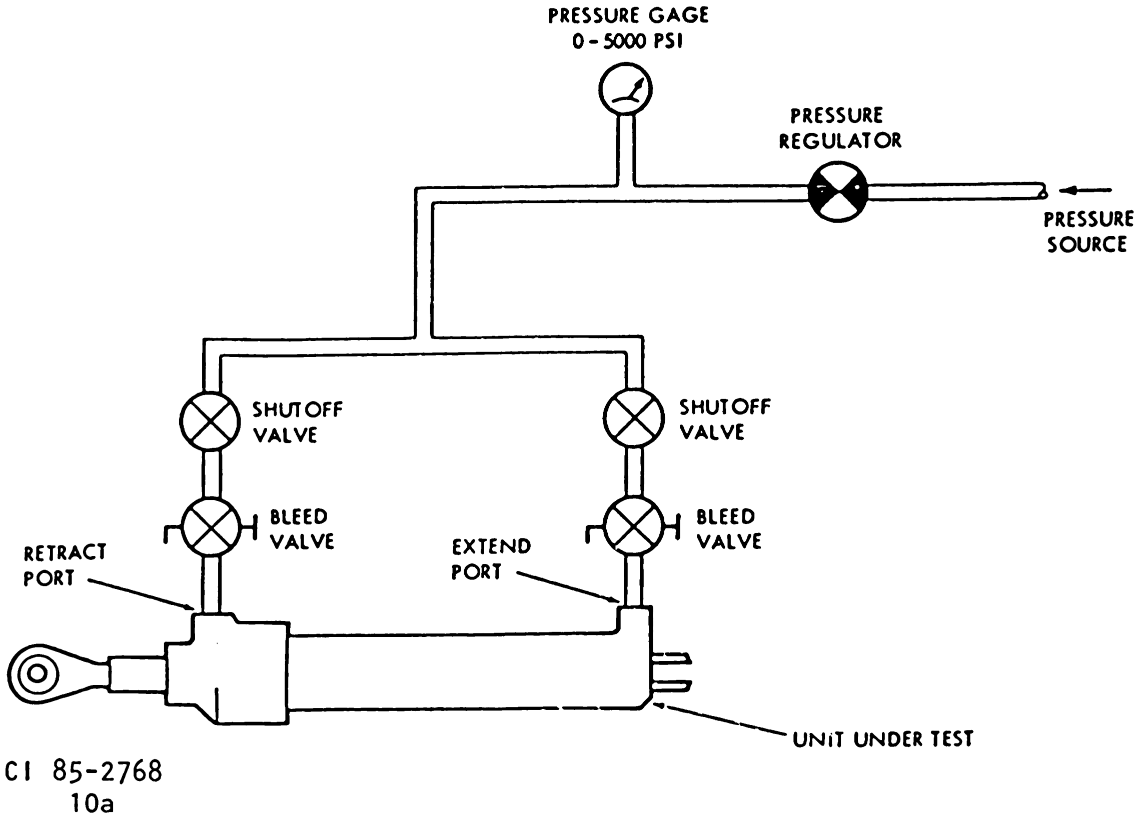


Figure 4–23. Speed brake actuator test set-up.

this, mask bearing (2) and fluid ports on barrel (20) and end cap (6) to prevent paint from being applied to these surfaces.

Cylinder Testing. Now that the cylinder is reassembled and adjusted, you are ready to test it. To test the actuating cylinder, you must use a hydraulic test stand capable of delivering controlled pressures up to 4500 psig. Install the cylinder assembly in a test setup similar to that illustrated in figure 4-23. Alternately apply 3000 psig fluid pressure to each cylinder port to cycle cylinder. Continue cycling until all air is bled from the unit; then perform the following tests.

Proof pressure test. With the piston rod retracted, apply 4500 psig pressure to the retract port. Hold the pressure for 2 minutes. Reduce pressure to 5 psig and hold for 2 minutes.

Next, extend the piston rod and perform the same test as stated above except pressure will be applied to the extend port. In either test stated above, there should be no evidence of permanent deformation or external leakage during performance of the test.

Leakage test. Cycle the cylinder (extend and retract) at least five complete cycles at 3000 psig operating pressure. There should be no evidence of binding or sticking. Leakage at the rod seal should not exceed TO specified limits. After satisfactory completion of testing, flush the cylinder with preservative hydraulic fluid, and drain and cap the cylinder ports.

Exercises (651):

1. While checking the overall length of the cylinder, you notice that it is longer than specified in the technical order. What can be done to bring the length within limits?

2. Explain why the paint should be stripped from the actuator.

3. What provision during reassembly of the actuator provides for alignment of the fluid ports?

4. To keep the rod end bearing in place, what should be done?

5. A small scratch is found inside the steel cylinder barrel of the actuator. What can be done to make this part serviceable?

6. How is the measurement taken for the overall length of the actuator?

Pneumatic System

UNLIKE HYDRAULIC fluid, the compressibility of air or other gases permits a large volume of air to be stored in small, high-strength containers. This permits the use of an aircraft pneumatic system that is light in weight and that creates fewer fire hazards than the conventional hydraulic system.

Some aircraft pneumatic systems employ a small compressor to maintain the pneumatic system at its desired operating pressure in flight. Other aircraft are simply serviced on the ground with pneumatic pressure and fly the entire flight without being serviced.

5-1. Pneumatic Systems Operation and Troubleshooting

In the early types of aircraft, a pneumatic system consisted of an air flask (charged to a specified pressure) used to operate one or more systems in an emergency. As you will see in this chapter, pneumatic systems can be, and in many cases are, much more complicated than this. In this section we are going to discuss a representative pneumatic power system and then deal with one of the subsystems that is supplied with pneumatic pressure from the basic system. After discussing these systems, we will point out typical malfunctions that occur in them and how to troubleshoot the systems.

652. State specified constructional/operational features of various pneumatic components in the pneumatic power system.

Pneumatic Power Supply System. In this discussion we have selected a pneumatic system that has just about everything you would normally find in a pneumatic system. Refer to figure 5-1. This system is a high pressure (3000 psi), self-sustained pneumatic system that supplies compressed air to the various pneumatic subsystems. Figure 5-1 only shows the pneumatic power supply system. Later on in this chapter we will show how a subsystem operates when we talk about the ram air turbine. But for now, we concentrate only on the pneumatic power supply system.

Pneumatic system components. The air compressor maintains the aircraft pneumatic system's pressurization during flight. The air compressor is driven by a hydraulic motor powered by the utility hydraulic system. Compressor operation is controlled by the pneumatic system's manifold pressure sensing switch. The compressor cuts in when system pressure drops to 2750 psi minimum, and cuts out when system pressure reaches 3050 to 3200 psi.

The moisture separator is capable of removing up to 95 percent of the moisture from the air compressor discharge line. The automatically operated condensation pump valve purges the separator oil-moisture chamber by means of a blast of air (3000 psi) each time the air compressor shuts down. The condensation dump valve solenoid is energized and deenergized by a pressure switch. When energized, it prevents the air compressor from pumping air overboard; when deenergized, it completely purges the separator reservoir and lines up to the air compressor. A filter protects the dump valve port from becoming clogged and thus insures proper sealing of the passage between the reservoir and dump port. An internal check valve protects the system against pressure loss during the dumping cycle and prevents back flow through the separator to the air compressor during the relief condition. The relief valve opens when system pressure reaches 3500 psi and reseats at 3250 psi to protect the system against overpressurization and thermal expansion.

The chemical air drier used in the high pressure pneumatic system further reduces the moisture content of air emerging from the moisture separator. It also serves to reduce the amount of air compressor lubricating oil and foreign material entering the subsystems.

An air servicing (schrader) valve is installed in the pneumatic system for the purpose of servicing the system while the aircraft is on the ground. The air filter in the ground charge line prevents the entry of impurities into the system from the ground servicing source. The air pressure gage, adjacent to the ground servicing valve, indicates the pressure of the system.

The hydraulic system consists of solenoid-operated selector valve, flow regulator, hydraulic motor, and motor bypass (case drain) line check valve. When the selector valve is energized, it allows hydraulic fluid under pressure to run the hydraulic motor. Deenergized, the selector valve blocks off hydraulic pressure, which stops the motor. The flow regulator meters the flow of fluid to the hydraulic motor, preventing excessive speed variation and/or overspeeding of the compressor. A check valve in the motor bypass line prevents the system return line pressure from entering the motor, thus, preventing motor stall.

Pneumatic system operation. Notice in figure 5-1 that the air compressor is mounted to the access door. When the door is down (as shown) the lubricating pump inside the

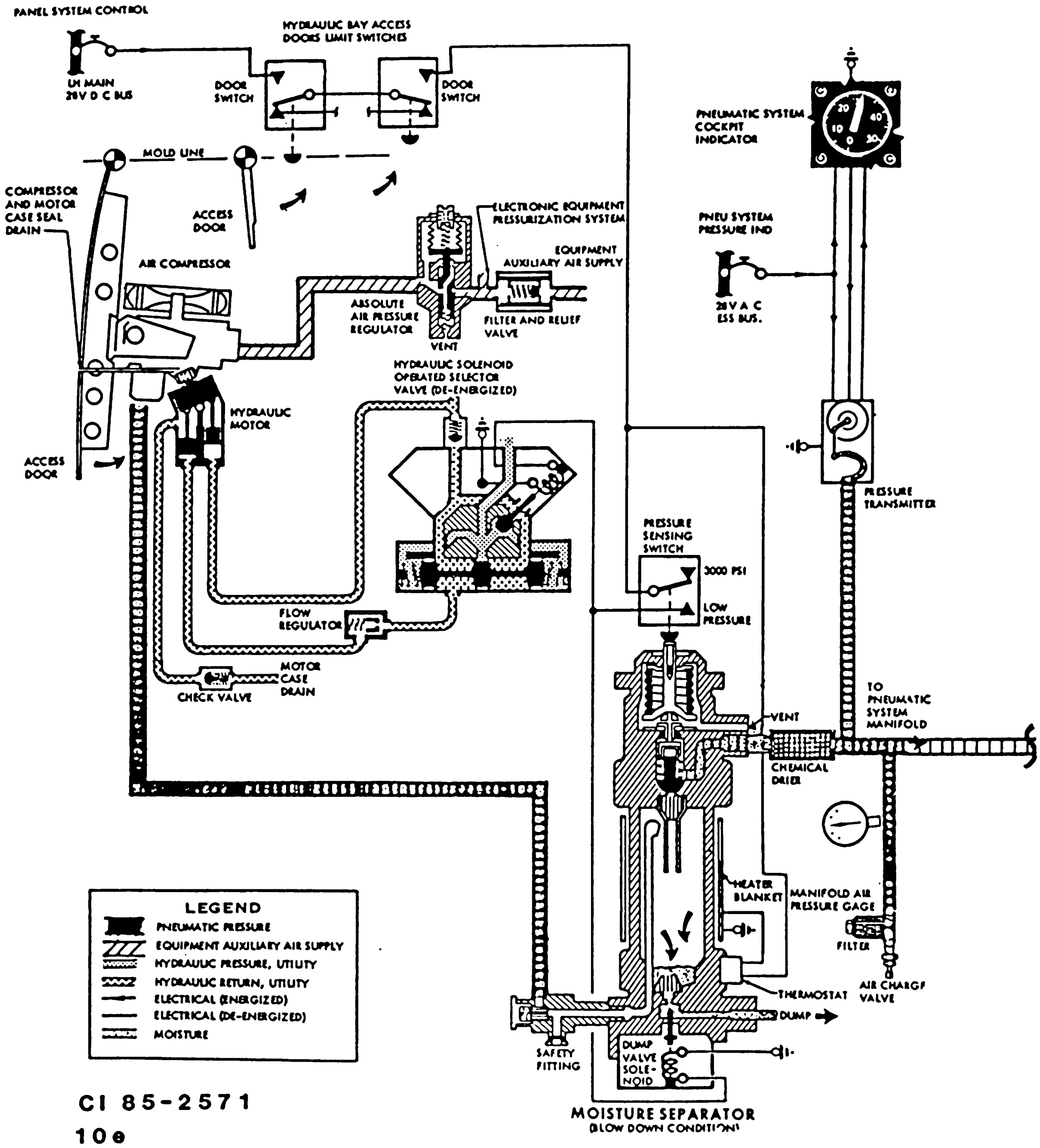


Figure 5–1. Pneumatic power system.

compressor would not lubricate all the moving parts properly. To prevent operating the compressor while the door is down, two switches are used to break the electrical circuit in the pneumatic system. Let's assume that the access doors are closed and the switches are actuated closed to complete the electrical circuit. Notice that the electrical power flows from the 28 VDC bus circuit breaker through the door access switches and down to the pressure sensing switch and heating blanket thermostat. If the temperature is low, the thermostat allows the electrical power to proceed on to the heating blanket. The heating blanket prevents the moisture inside the moisture separator from freezing. If the pressure sensing switch is closed, notice that the power can energize the moisture separator dump valve and the solenoid-operated hydraulic selector valve. When the solenoid-operated selector valve is energized, it directs hydraulic fluid under pressure through the flow regulator to the hydraulic motor attached to the air compressor. As the motor turns, it causes the compressor to build up pneumatic pressure. Notice the seal drain on the access door. Any leakage on the shaft seal of the hydraulic motor will come out this area.

The equipment auxiliary air system supplies the air compressor with air when the engines are operating. This

insures an adequate supply of air to the compressor at all altitudes. The auxiliary air is first filtered through a high-temperature 10-micron filter that has a built-in relief (bypass) valve. After it flows through the filter, it enters a pressure regulator. The air pressure regulator provides a stabilized source of air to the inlet port of the air compressor. The air compressor being run by the hydraulic motor compresses the inlet air and sends it out the pneumatic pressure line to the moisture separator. Since the solenoid on the bottom of the moisture separator is energized closed, the pneumatic pressure will flow up through the check valve and out to the exit port. The pressure will next flow through a chemical drier and out into the pneumatic system manifold. Notice also that the pressure can flow to the pneumatic system pressure transmitter, which sends an electrical signal to the pressure indicator in the cockpit.

When pressure builds up to the specified amount in the system, the pressure switch on top of the moisture separator opens. When this happens, the solenoid on the hydraulic selector valve deenergizes, and the air compressor hydraulic motor stops running. At the same time, the solenoid on the bottom of the moisture separator is also deenergized. The dump valve automatically springs open. When this happens, any moisture in the moisture separator is dumped overboard. The system will remain in this position until the pressure decreases enough to cause the pressure switch to be activated again.

Exercises (652):

1. Tell why the air compressor should not be operated while the access door is hanging down.

2. What provides a stable pressure head to the air compressor inlet port?

3. If the shaft seal is leaking on the hydraulic motor, how would this be indicated?

4. If the temperature is below freezing, what prevents the moisture in the moisture separator from freezing?

5. What components are provided for external servicing of the pneumatic system?

6. What protects the dump valve port of the moisture separator assembly from becoming clogged?

7. What two components are energized when the moisture separator pressure switch is closed?

653. State specified construction and operational features of a ram air turbine (RAT) pneumatic actuating system.

Pneumatic Subsystem. On some aircraft a Ram Air Turbine (RAT) is installed for emergency use. The turbine itself is similar to a child's pinwheel in that, as the wind strikes the pinwheel, it turns. The turbine works under the same principle because as the turbine is put into the airstream as the aircraft is flying it also causes the turbine to turn. Depending on the aircraft involved, the RAT could be used to drive a hydraulic pump or an electrical generator. In the system that we have selected (fig. 5-2) the RAT is used to drive a small AC generator. This generator produces enough power for the emergency operation of the aircraft in case the main source of electrical power should fail. The turbine is designed to maintain generator output until the aircraft speed drops to approximately 90 knots. This assures the pilot of emergency AC power until touchdown. The RAT control handle is located in the cockpit. Movement of the handle allows pressure from the basic pneumatic system (which was previously discussed) to extend or retract the RAT. Let's discuss briefly the construction and operational characteristics applicable to this system. As stated earlier the RAT requires basic pneumatic system pressure to position the turbine into the air stream. As you can see from figure 5-2, the pneumatic pressure enters from the basic pneumatic system through a check valve. This check valve is installed to prevent the RAT system pressure from being depleted in case the basic pneumatic system pressure should fail. Pressure then flows to a relief valve, which will open and vent pneumatic pressure overboard if the pressure rises too high. The direct reading gage will indicate the amount of pneumatic system pressure in the RAT system. The selector valve is a poppet type that has two positions: RAT-IN and RAT-OUT. Pay particular attention to the vent port of this valve, since it does not route the air back to return but dumps the air overboard. The selector valve is mechanically operated by movement of the RAT-IN and RAT-OUT handle in the cockpit. Figure 5-2 shows how the system components are positioned when the RAT is out. To insure proper sequencing of the system, sequence valves are used. These valves insure that the door is open prior to any movement of the turbine. The procedure is reversed during the retract cycle. The two-way restrictors limit the speed of the door and turbine operation.

Since the selector valve is a 2-position valve, pressure will be available in either the out or in lines at all times depending on which way the valve is selected. Let's go through one complete cycle of extending and retracting the RAT to see how it operates. By positioning the selector valve, as shown in figure 5-2, pneumatic pressure is routed to both the turbine and door actuating cylinders at the same time. With the turbine and door closed the door sequence valve will be open and the turbine sequence valve will be

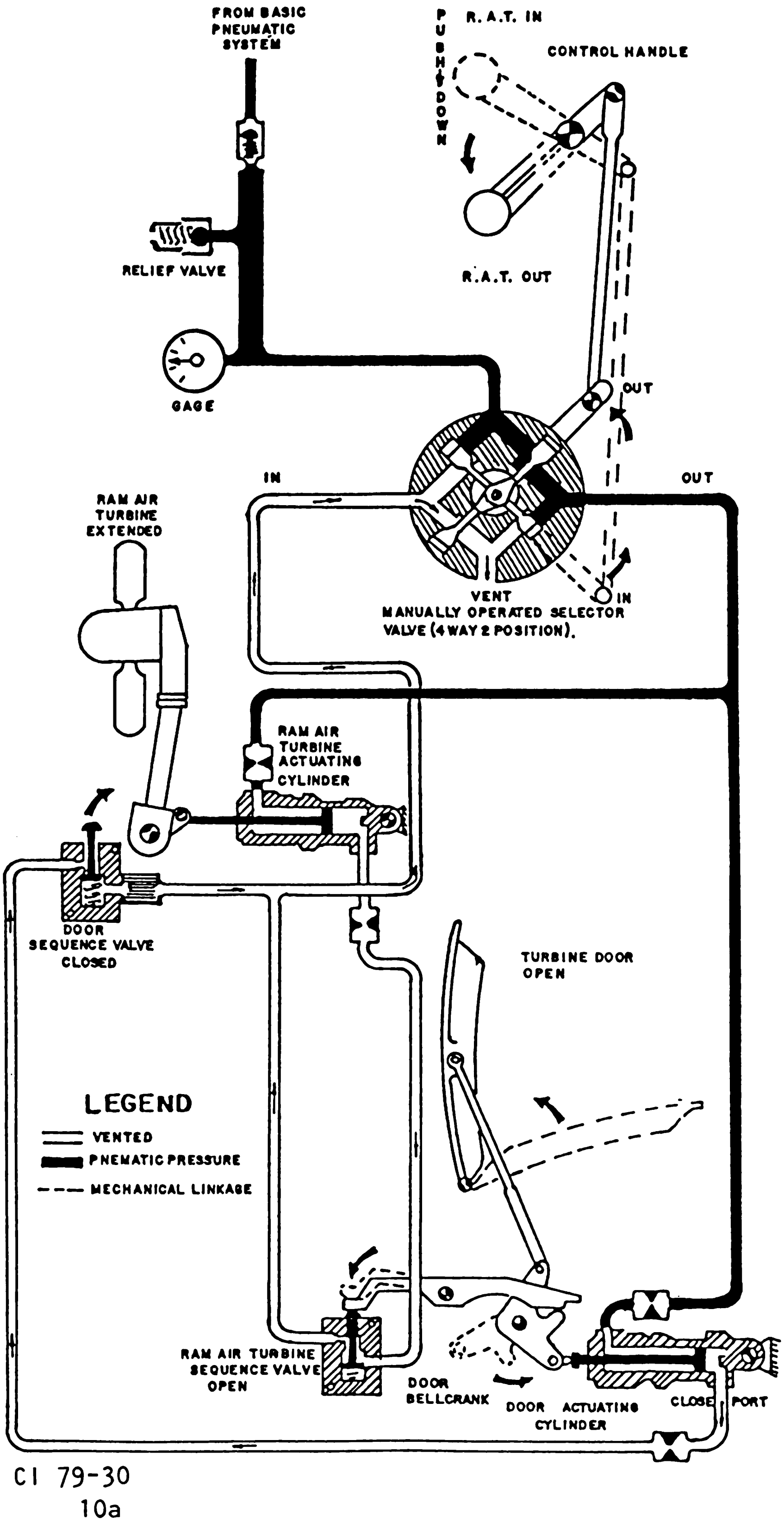


Figure 5–2. RAT system.

closed. With the sequence valves positioned as such the pneumatic pressure to the door actuator will cause the door to open. The air pressure on the back side of the actuator will be routed through the open door sequence valve and back to the vent port of the selector valve. Once the door is completely open a lever attached to the door bellcrank will push the turbine sequence valve open. Now the pressure to the turbine actuating cylinder can be routed through this sequence valve and back to the selector valve. With the selector valve in this position notice that pressure will remain on the out lines of the system to insure that the RAT stays out. Now let's go through a RAT-IN cycle. By placing the selector valve to the RAT-IN position notice that the cam in the center of the selector valve will force the other poppets in the selector valve off seat while the two other poppets return on seat. When this happens pneumatic pressure is routed to the door sequence valve, which is closed at this time. Since pressure can't go through the sequence valve it flows on down to the turbine sequence valve, which is open. Air pressure passes through the turbine sequence valve up to the turbine actuating cylinder. The actuator forces the turbine to the IN position. The air on the opposite side of the piston in the actuator is now routed back to the selector valve, which is then vented overboard. Once the turbine is completely in, it contacts the door sequence valve and pushes it to the open position. Notice that the door can now close, since the air pressure on the opposite side of the door activating cylinder piston can be routed back through the open door sequence valve to the selector valve. When the door closes, notice that the turbine sequence valve is forced closed by the spring inside the sequence valve. Here again, even though the turbine is in with the door closed, pneumatic pressure is available to keep the turbine down and the door closed.

Exercises (653):

1. What units insure that the turbine and door operate in the proper order?

2. What happens to the air that is returning to the selector valve?

3. Why are Ram Air turbines installed on aircraft?

4. What insures the RAT stays out?

5. What position is the turbine sequence valve in when the door is completely open?

6. For what specific reason is the check valve installed in this system?

654. Given a hypothetical troubleshooting situation, state the most probable causes for pneumatic system malfunction.

Troubleshooting Pneumatic Systems. A pneumatic system involves the use of high pressure air as a source of pressure for either normal or emergency operation of various aircraft subsystems. As we have mentioned previously, you will be responsible for troubleshooting not only the hydraulic systems but also the high-pressure pneumatic systems as well. You must couple your knowledge of the system with the knowledge of probable troubles and remedies prior to the actual troubleshooting of the system. You can accomplish this by thoroughly researching all available information and schematic drawings pertaining to the system. Most pneumatic system malfunctions will be largely the result of leakage of the stored system air. Although other troubles may occur, leakage is by far the most common problem that the pneudraulic specialist is called upon to remedy. The procedures for locating leaks include listening for escaping air, conventional bubble check, and the use of the ultrasonic leak detector.

If an abnormal leakage of air has been reported, do not service the system until it has been inspected for leaks. If a complete loss of pressure has been reported, and the inspection reveals no apparent defect, it will be necessary for you to pressurize the system to determine the cause of the malfunction. (WARNING: Because high-pressure pneumatic systems are fast acting in operation, all ground safety rules should be strictly observed to prevent injury to personnel and damage to the equipment.) Before servicing a high-pressure system, check to insure that all components have been connected properly and that all control valve handles and switches are in their proper position.

We mentioned earlier that you can properly diagnose some of the unit malfunctions of a pneumatic system by studying a schematic drawing of the system. To familiarize you with how this is done, several troubles and causes are listed below which are based on the typical 3000 psi system shown in figure 5-1 and the RAT system shown in figure 5-2. While studying these troubles, you can see how systematic analysis can help you determine the actual cause of a malfunctioning pneumatic system. In the following troubles we will assume that the system is free from pneumatic leaks caused by tubing and fitting leaks. Let's start first with the pneumatic power system as shown in figure 5-1.

Pneumatic power system. One of the common problems with this system is that the air compressor will not run. In order for the air compressor to run, the hydraulic selector valve must be electrically energized. For the electrical circuit to be complete, the electrical (28 VDC) power must go through a fuse, two door switches, and a pressure switch on top of the moisture separator. As stated previously, the

air compressor must be lubricated by lubricating oil inside the compressor. If the compressor is in the down position, as shown in figure 5-1, the door switches will prevent the compressor from operating. So be sure that the air compressor is in the horizontal position and that the access doors are closed. As you can see this will complete the circuit from the 28 VDC bus to the pressure switch on the moisture separator. If the pressure switch malfunctions or the system is above the normal operating range of the pressure switch, the circuit will be broken. Next comes the solenoid-operated selector valve itself. If the solenoid in the valve has a malfunction it will prevent the valve from operating. While we're on the electrical portion of the system, notice that the moisture separator has a circuit for heating the moisture separator and also a dump valve on the bottom of the moisture separator. The heating blanket on the moisture separator will be controlled by a thermostat. If the blanket is not operating, more than likely the thermostat has malfunctioned. The dump valve on the other hand is energized closed and spring loaded opened. If the electrical power should fail, the valve will automatically spring open, dumping the pressure in the moisture separator overboard. If the air compressor is running and pneumatic pressure continues to flow from the dump port of the moisture separator, a wire is broken or the dump valve has malfunctioned. If the electrical circuit is completed to the selector valve, what could possibly happen to the hydraulic system? Well, for one thing if the motor overspeeds, the flow regulator in the pressure line between the selector valve and hydraulic motor will probably malfunction. If the motor is turning and yet no pneumatic pressure is available at the outlet port of the compressor, more than likely the compressor runs but system pressure will not build up, the rupture disc on the safety fitting is probably blown out or the solenoid-operated dump valve is inoperative. In some cases the air compressor does not cut in within limits; this indicates a bad pressure switch. If the direct reading gage does not agree with the indirect reading gage, a test gage may have to be temporarily installed to determine which gage is functioning properly. If the basic pneumatic direct reading gage is incorrect, it will have to be replaced. If the indirect reading gage has malfunctioned, it should be adjusted. If it can't be adjusted, the transmitter or indicator will have to be replaced. Sometimes when the moisture separator valve is deenergized the pressure in the pneumatic system manifold will drop off. If no external leakage is evident, the check valve inside the moisture separator is probably leaking. This allows the pressure in the pneumatic pressure manifold to flow past the check valve and exit through the moisture separator dump line.

Pneumatic subsystem. Now let's look at some of the things that could malfunction in the RAT subsystem. We'll start with the check valve in the pressure line to the selector valve. (Refer to fig. 5-2.) This valve is installed to trap the pneumatic pressure in the RAT system. As an example, if the basic pneumatic systems pressure should be deleted, the check valve will trap the air in the system. If this valve were to leak internally, the pressure in the RAT system will also be depleted. If the basic pneumatic system shows the proper amount of pneumatic pressure and the RAT system differs from this, one of the gages must be checked to see if it has malfunctioned. Now, what if the selector valve is positioned to the out position, but the door does not open fully? This is probably caused by improperly rigged door linkage. If the turbine does not go out fully, the turbine actuator rod end will have to be adjusted. If the turbine doors are not fully open when the turbine starts to go out, the air turbine sequence valve is adjusted improperly or is leaking internally. If the turbine and doors open/close too fast or too slow, the orifice restrictors will have to be checked. As stated previously, the RAT system will have pressure applied to either the out or in position at all times. Air coming from the vent port of the selector valve could mean that one of the actuators or the selector valve itself is leaking internally.

Exercises (654):

Use figures 5-1 and 5-2 to solve hypothetical situations listed below.

1. Using figure 5-1, what could be the problem if the dump valve is closed and yet the hydraulic selector valve will not operate?

2. What could cause the pressure to build up slowly if the air compressor is operating normally and producing an air flow?

3. Using figure 5-2, determine which sequence valve is maladjusted if the door closes before the turbine is fully in.

4. Which actuator is probably leaking internally if air comes from the RAT selector valve when the RAT is out but does not leak when the RAT is in? Why?

5-2. Bench Check and Repair of Pneumatic System Components

Although the pneumatic system is basically made up of a storage bottle, selector valve, and actuator, there are many more components that are quite complicated. Many pneumatic components can't be bench checked and repaired because of TO limitation, yet others can be completely bench checked and repaired. As an example, the moisture separator is one item that has limitations on its repair; but if you had the proper equipment, there is no reason that you couldn't bench check it to see if it was functioning properly. On the other hand, you can bench check and repair the sequence valve in its entirety.

655. Specify how to bench check a pneumatic moisture separator to determine if it is functioning properly.

Moisture Separator Testing. Many units located on the aircraft cannot be repaired because the –6 TO strictly forbids it. This doesn't mean that you can't test a unit to determine if it is functioning properly, especially if your shop is capable of doing so. Here, we will consider some basic tests that can be done by just about any pneudraulic shop. These tests are simple but they must be done with care because working with pneumatic pressure is very dangerous.

We previously explained how the moisture separator worked. From that explanation you learned that the moisture separator is made up of many different units, such as the check valve, solenoid-operated dump valve, pressure switch, and heating blanket. Here, we will tell you how you can check these units to determine if they are working properly.

Check valve. To check this valve there are two distinct tests that will have to be done. They are the check valve opening pressure test and the reverse flow test.

a. Check valve opening pressure test. This test is done to determine if the check valve is opening at the proper pressure testing. To do this, install the moisture separator assembly in a test set-up similar to that in figure 5-3. Notice that the condensate sump outlet port is capped and the pressure outlet line is submerged in a beaker of water. The pressure inlet line is attached to 100 psig air supply source which has an inlet shutoff valve and pressure gage attached. With this arrangement, adjust inlet valve to slowly pressurize the moisture separator assembly. Bubbles from the leakage tube indicate that the check valve has become unseated. When this happens check the pressure gage reading. The gage reading should be anywhere from 10 to 60 psi.

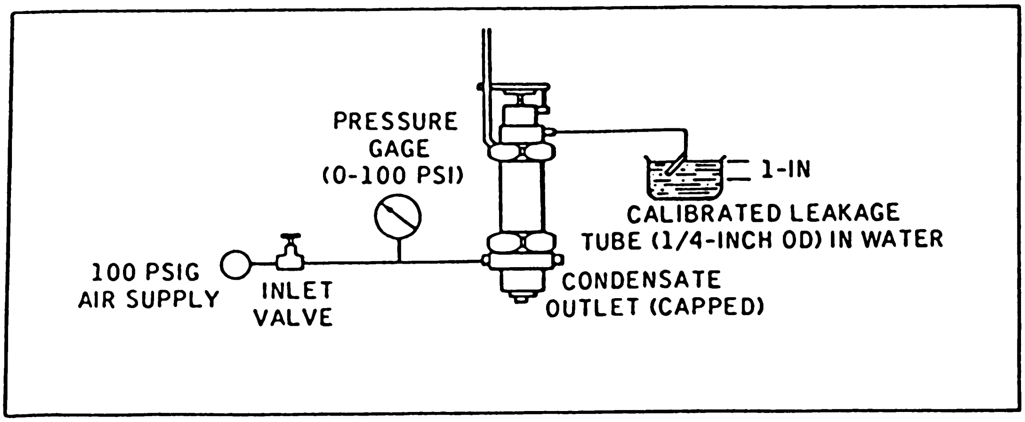
b. Check reverse flow test. Use this test to see if the check valve is seating properly. Connect the moisture separator assembly to a pneumatic pressure source as shown in figure 5-4. Pressurize the moisture separator assembly to a pressure of 3000 psi and check for leakage out the pneumatic pressure inlet line of the moisture separator. If leakage is evident, it will cause bubbles to form in the water.

Solenoid operated dump valve. For this test, connect the moisture separator assembly as shown in figure 5-5. Pressurize the moisture separator assembly to a pressure of 3000 psig. Since the solenoid-operated valve is spring loaded to the close position when deenergized, the valve should be closed at this time. Any leakage past the solenoid-operated valve will show up as bubbles in the water.

Install the moisture separator assembly as illustrated in figure 5-5, except with the leakage tube removed from the condensate sump outlet. Be certain that the condensate sump outlet is vented in a direction where condensate blow-down will not cause injury or damage. Now apply pressure with the inlet valve until the pressure switch breaks circuit to the 27-volt bulb and the condensate exhaust valve opens. The cut-out pressure will be indicated by the light going out. Using the bleed valve (located in the pressure outlet line), lower the air pressure until action of the pressure switch turns on the 27-volt bulb and closes the condensate exhaust valve. When the light turns on, it will indicate the cut-in pressure of the pressure switch.

Heating blanket continuity test. Measure resistance through the heating blanket with an ohmmeter, while flexing the blanket as a test for intermittent open circuits. The electrical circuitry can be seen in figure 5-6. Resistance through the blanket must be within specified limits of the TO.

These are only some of the tests that can be done without any special test equipment. Of course, with the test equipment authorized, this unit could be checked thoroughly without any difficulty.



CI 79-31
10a

Figure 5–3. Check valve opening pressure test.

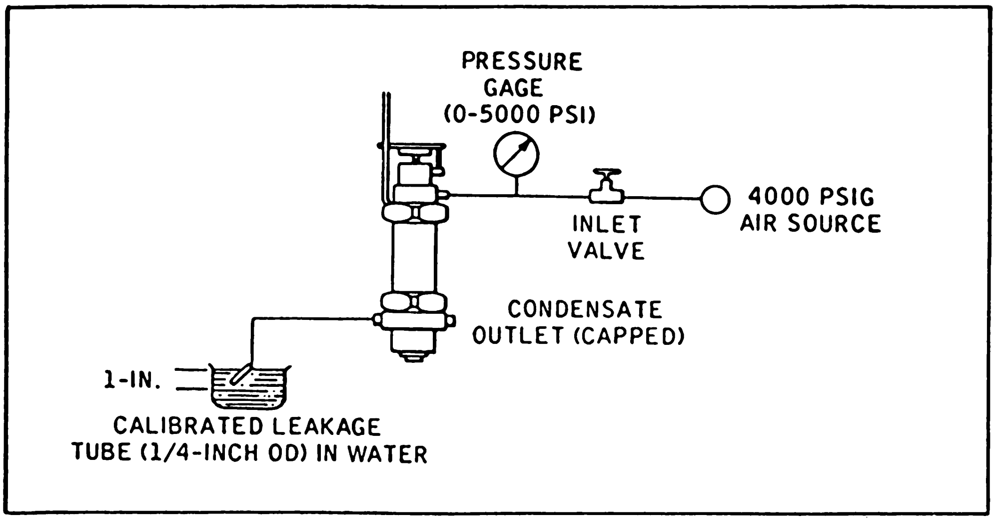


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Figure 5-4. Check valve reverse flow test.

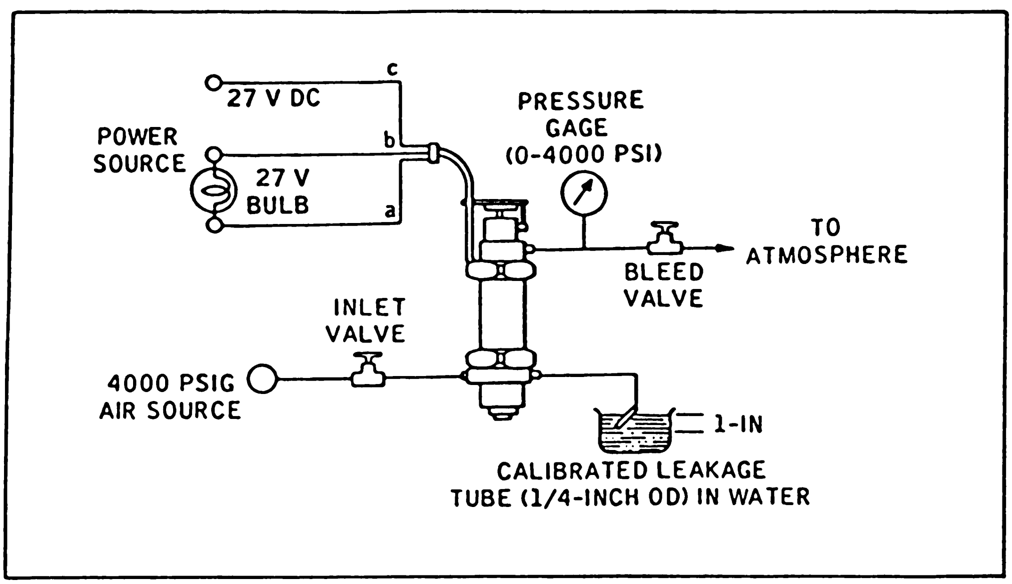

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Figure 5-5. Check of solenoid-operated dump valve.

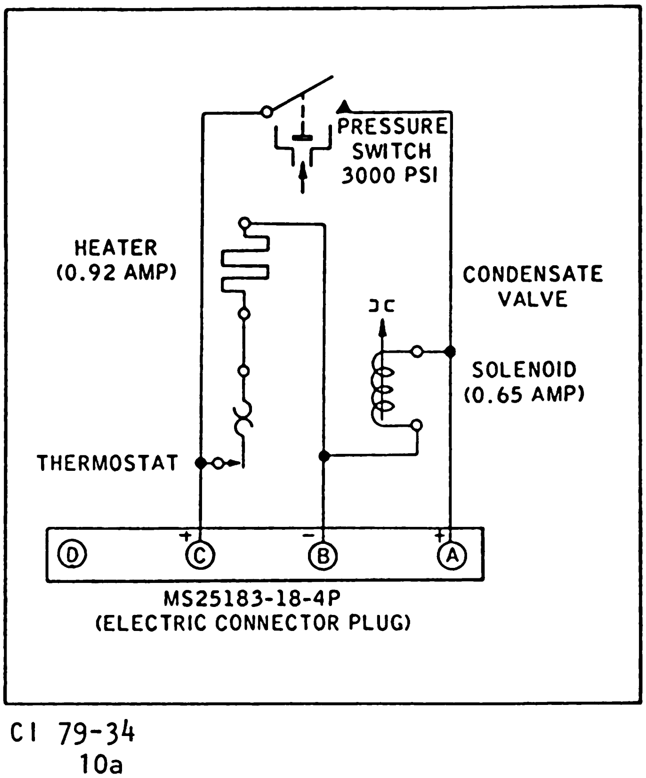


Figure 5-6. Moisture separator electrical circuitry.

Exercises (655):

1. Using figure 5-4 determine how you would know if the check valve is closing properly.

2. If the pressure switch turns the light out in the test set-up, as shown in figure 5-5, what would this indicate?

3. How can you check the heating blanket for intermittent open circuits?

4. How could the check valve in the moisture separator be checked to see if it is opening properly?

5. With the moisture separator installed in the test set-up, as shown in figure 5-5, what would be the problem if the light is on but air continues to flow from the dump port?

656. Specify how to bench check and repair a pneumatic sequence valve.

Bench Check and Repair of Sequence Valve. One of the items that consistently malfunctions in the RAT system previously described in this chapter is the sequence valve. This valve, although small and unimpressive in appearance, can cause you many headaches if it is not bench checked and repaired properly. Let's look at the procedures you would use when bench checking and repairing this particular unit. First, disassemble the unit in the order of index numbers as shown in figure 5-7. After disassembly, clean all parts with dry cleaning solvent and dry them with clean, dry, low-pressure air. Next, inspect all parts for structural defects, scoring, galling, and corrosion. Some of the parts will have to be measured to see if they are worn beyond limits specified in the TO. For example, the springs (6, 16) will have to be measured for length and compression load. Inspect all metal parts for cracks by subjecting nonferrous parts to fluorescent penetrant inspection and all ferrous (iron) parts to magnetic particle inspection. Then inspect all threads for burrs and evidence of stripping. Replace all parts that fail to meet inspection requirement, as well as all 0-ring seals. Many of the repair parts for the valve are provided in a kit. Replace all disassembled parts, regardless of condition, that are removed in the process of disassembly, with parts furnished in the kit. An assembled part which is not defective need not be disassembled solely for the purpose of replacement by corresponding kit part. In other words, you don't have to tear a complete unit apart to replace a part, just because the part is in the repair kit. In some cases a seal may be the only thing that causes a malfunction. After you have acquired all the parts, you are ready for reassembly. Reassembly is simply a reversal of the disassembly, except that all internal parts will have to be lubricated with pneumatic grease (MIL–G–4343). After reassembly you are ready for testing. (WARNING: Perform the tests with the sequence valve in a safety test chamber to prevent injury due to valve rupture.)

To begin the testing, plug the outlet port and connect air pressure source to the inlet port. Apply 4500 psi proof pressure and check for leakage. No external leakage is allowed. Next, reduce the pressure to zero and remove the plug from the outlet port. Connect the air pressure source to the outlet port. Then attach a U-shaped hose to the inlet port with the other end of the hose in an inverted, submerged beaker full of water. With the valve connected in the test set-up, as shown in figure 5-7, gradually apply pressure until 3000 psi is reached. Now check for external and internal leakage. Decrease the pressure to 50 psi and check again for internal and external leakage. Remove the hose from the water and depress the sequence valve plunger and check for air from the hose. Be careful that the air flow is directed away from nearby personnel. After you determine that the plunger is opening the valve properly, remove the valve from the test set-up, and safety wire and plug the ports.

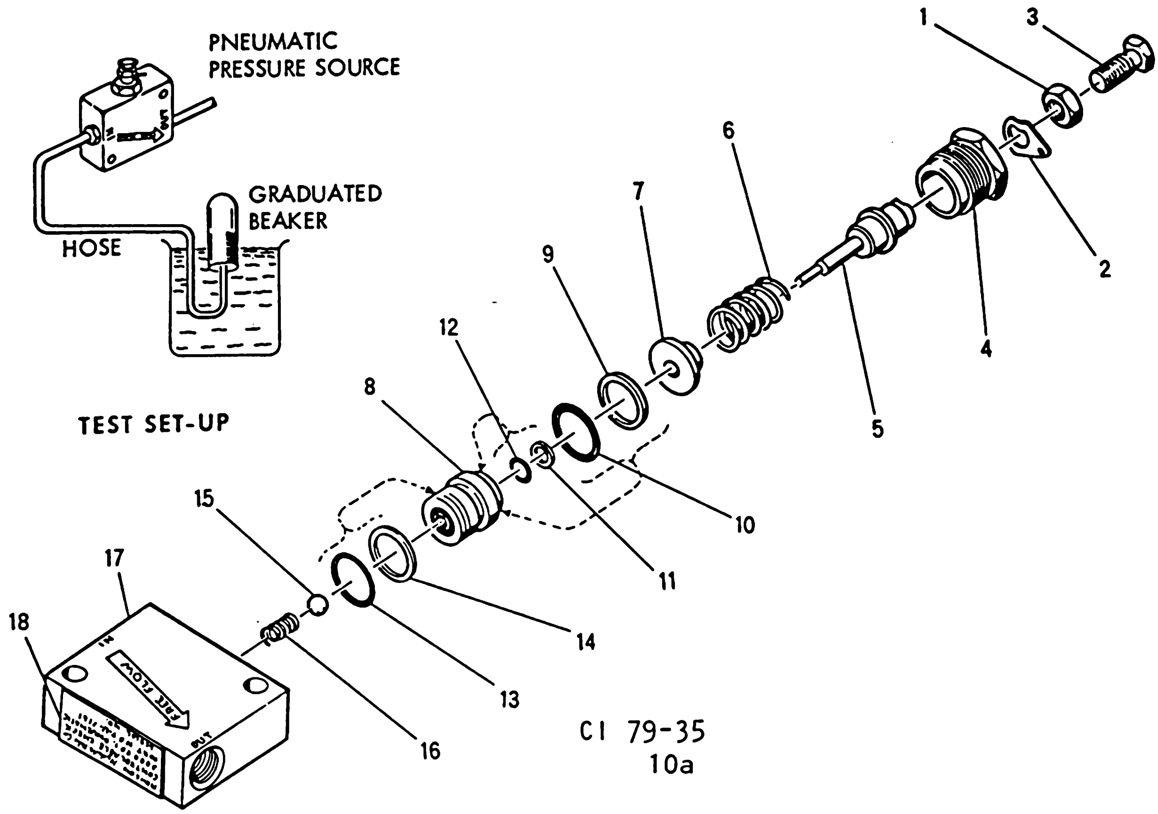


Figure 5-7. Sequence valve breakdown and test.

Exercises (656):

1. How should nonferrous parts be inspected for cracks?

2. When proof pressure is applied to the sequence valve, what port should it be applied to?

3. Explain why testing a pneumatic sequence valve is dangerous.

4. How do you determine that the valve is opening properly?

Inflight Refueling System

ON 12 NOVEMBER 1921, Wesley May, with a 5-gallon can of gasoline strapped to his back, climbed from the wing of a Lincoln Standard flown by Frank Hawks to the wing skid of a Curtiss JN–40 piloted by Earl Daugherty. He slowly made his way to the engine and poured gasoline into the tank. The era of inflight refueling had began.

The Air Force became interested in this new technique and, during the years that followed, took steps to develop it. Finally, on 1 September 1953, information was released about the first inflight refueling of jet-powered aircraft. A B–47 Stratojet had received fuel in the air from a KB–47B.

A year later, between 17 and 19 November 1954, a USAF B–47 Stratojet bomber broke all existing jet endurance records by shuttling nonstop between England and North Africa in 47 hours, 35 minutes. Inflight refueling made this 21,000 mile flight possible.

A few years later, on 18 January 1957, three B–52 Stratofortresses commanded by Major General Archie J. Old, Jr., USAF, completed a 24,325-mile round-the-world nonstop flight in the record time of 45 hours, 19 minutes. The average speed was 534 mph. This was the first globe-circling nonstop flight by jet aircraft. Once again, inflight refueling techniques made this flight a reality. The era of ultra-long range flight had begun.

Not to be left out of the picture, on 2 December 1964, four F4C Phantom jet fighters performed another amazing inflight refueling feat. These supersonic, high-altitude jets completed a nonstop, 18 hour flight of 10,000 miles, averaging 555 mph. The tankers used were KC–135s.

We have come a long way from the days of the Lincoln Standard. Today, because of inflight refueling advancements, our aircraft can reach the farthest points in the world. As a *pneudraulic system mechanic,* you are responsible for the maintenance of the air refueling (A/R) system. To maintain this system, you must be familiar with the construction, operation, repair, and servicing of the units in the system. This chapter provides the knowledge that you need to perform these tasks and is devoted to the inflight refueling (A/R) systems found on a tanker aircraft and the air refueling receiver (A/RR) system.

6-1. Air Refueling System

The A/R system provides a means of transferring fuel from a tanker airplane to a receiver airplane while in flight. The boom is equipped with a nozzle for automatic attachment to the receptacle installed on the receiver airplane (fig. 6-1).

To operate properly, the A/R system is comprised of several other systems, the hydraulic, electrical, and fuel systems. In this section we will talk about the boom operator's compartment, the A/R exterior lighting system, fuel feed system, hydraulic systems, and the A/R signal system.

657. Identify the controls on the boom operator's compartment and specify their operation/purpose.

When you are performing maintenance on various air refueling units, you may need to operate the unit or the system in which the unit functions. Therefore, you should be familiar with all of the units within the boom operator's station, such as the compartment, the boom telescope lever, and the ruddevator control stick.

Notice in figure 6-2 that the boom operator lies on a pallet facing aft. The boom operator's periscope is installed to provide the boom operator with a large field of vision aft of the aircraft. Notice also that the boom operator has his or her right hand on the ruddevator control stick.

Boom Operator's Compartment. Figure 6-3 shows a typical boom operator's compartment. This compartment houses the various controls, instruments, circuit breakers, and miscellaneous equipment that you operate, observe, or use. You may have to use these items whenever you perform ground maintenance. Study the compartment in detail.

Figure 6-3 is only a representative panel. The panel you work on may have slight variations in locations. It may also have a small communication panel on its left side. In addition, it may contain an oxygen panel. Despite these variations, most will be very similar to the one in figure 6-3.

In addition to the information given in figure 6-3, we will discuss three control units as they apply to a representative A/R system. These control units are the boom hoist lever, boom telescope lever, and the ruddevator control stick. Locate these items in figure 6-3 as we discuss them.

Boom hoist lever. The A/R boom hoist lever is located on the left side of the boom operator, outboard of the boom position instruments. The lever has a guarded FREE WHEEL position, which allows the boom to be flown aerodynamically by positioning the ruddevators with the ruddevator control stick. When the hoist lever is positioned to HOLD, the boom remains in a fixed position. When the hoist lever is positioned to either LOWER or RAISE, the rate of hoisting or lowering depends upon how far the lever is advanced.

Boom telescope lever. The A/R boom telescope lever is located on the left side of the boom operator, outboard of the boom position instruments. When this lever is advanced

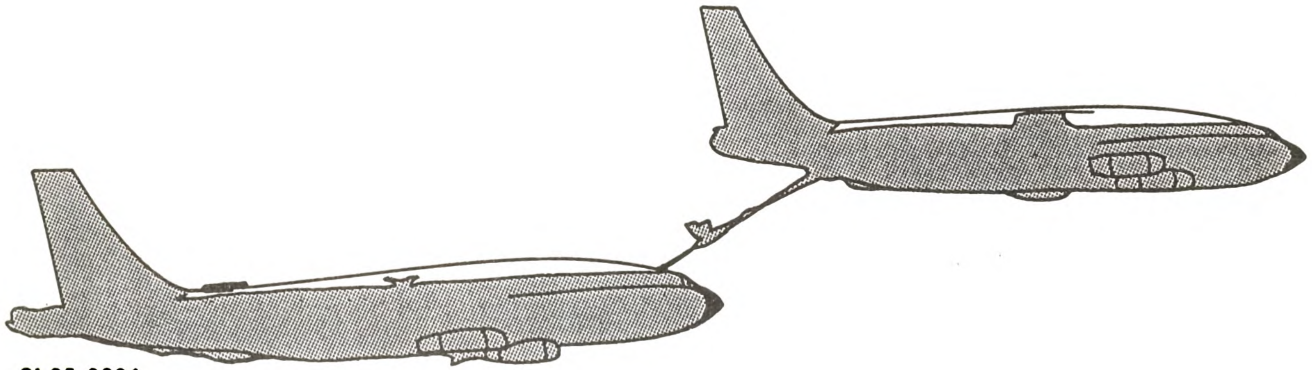


Figure 6–1. Inflight refueling.

to either side of the NEUTRAL position, it controls the rate of telescoping of the boom. The lever is spring-loaded to the NEUTRAL position by a bungee assembly located in the sighting door compartment. Advancing the lever aft extends the boom, while pulling it forward retracts the boom. During contact MADE, the lever is in the NEUTRAL position. The telescope lever has a thumb switch, which controls the pilot director lights. When pressed momentarily by the boom operator, this switch flashes the lights as a breakaway signal to the receiver airplane.

Ruddevator control stick. The ruddevator control stick is located to the right (when the boom operator is in position for refueling) and slightly below the operator. The control stick rotates the ruddevators to position the boom in flight. When this stick is rotated upward, it raises the boom in elevation. When rotated downward, it lowers the boom. Sideway rotation of the control stick moves the boom in azimuth. The control stick contains two thumb switches and a trigger switch. The thumb switches are the interphone and microphone switches. The trigger switch is the A/R disconnect switch.

Exercises (657):

1. Match each control in column B with its operation/purpose in column A. Some of the controls in column B can be used more than once.

Column A	*Column B*
____ (1) Used to extend and retract the boom.	a. Boom hoist lever.
____ (2) Used to fly the boom.	b. Boom telescope lever.
____ (3) Has four positions, raise, lower, hold and free wheel.	c. Ruddevator control stick.
____ (4) Moves the boom in azimuth.	
____ (5) Has a switch that can be used for disconnect.	

658. Specify construction and operation features of the A/R boom.

The Air Refueling Boom. The A/R boom is a telescoping tube. Figure 6-4 is a simplified drawing of the A/R boom. Notice that the boom consists of two telescoping tube assemblies (3 and 7), referred to as an outer structural tube and an inner structural tube, that connect to the A/R fuel system through a flexible fuel coupling (2). The boom is telescoped with a sprocket-driven chain (12) and cable (10), which are attached to the inner structural tube. The sprocket is driven by a reversible hydraulic telescope motor (6) through a reduction gear telescope drive assembly (8). The boom is approximately 27 feet 8 inches long when retracted, and approximately 47 feet 3 inches when extended. The inner fuel tube (14) extends approximately five-sixths of the way from the terminal end of the boom through the outer structural tube. The outer surface of the inner fuel tube forms a sliding seal, with Teflon ring seals at the forward end of the inner structural tube. The ring spring assembly (15) cushions the inner structural tube when it reaches either limit of its travel. Not to be confused with the ring spring assembly is the shock absorber recoil assembly (16). This boom component attaches the nozzle to the boom inner structural tube and absorbs impact during refueling contact. Two tandem-mounted surge boots (11 and 13) connect between the outer fuel tube (5) and the shock absorber recoil assembly. The boots are inflated with dry air to absorb high fuel pressure surges that occur during refueling or while disconnecting from the receiver aircraft. Mounted at the forward end of the outer structural tube are elevation and telescoping electrical control units (not shown). These control unit switches are discussed in a following objective.

The entire length of the outer structural tube mounts hydraulic lines for a fuel dump (jettison) actuator (17) and the ruddevator power controls (not shown). A ruddevator

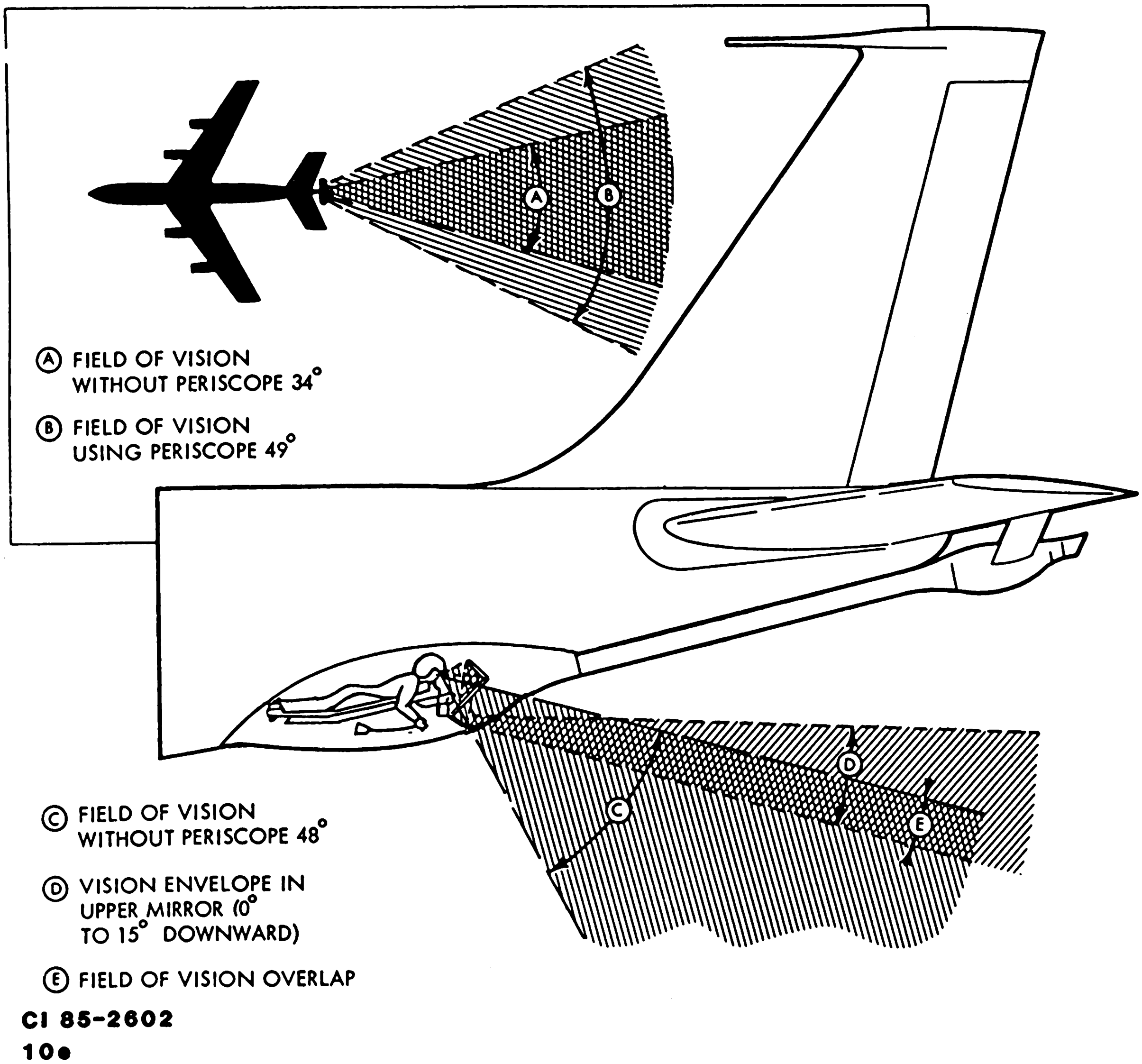


Figure 6–2. Position of boom operator.

lock system, boom latch eye, and boom stowage shock absorber (9) are also mounted on the outer structural tube. Two roller brackets, each of which contains four rollers, are installed on the outer structural tube. One bracket is approximately three-fourths of the way down the tube. The outer bracket is installed at the aft end. These rollers center and support the inner structural tube and provide minimum friction during telescoping. The entire length of the boom is enclosed in streamlined fairing. The gland seal (4) prevents leakage between the inner fuel tube and outer fuel tube.

Exercises (658):

1. What component of the boom cushions the inner structural tube when it reaches its limit of travel?

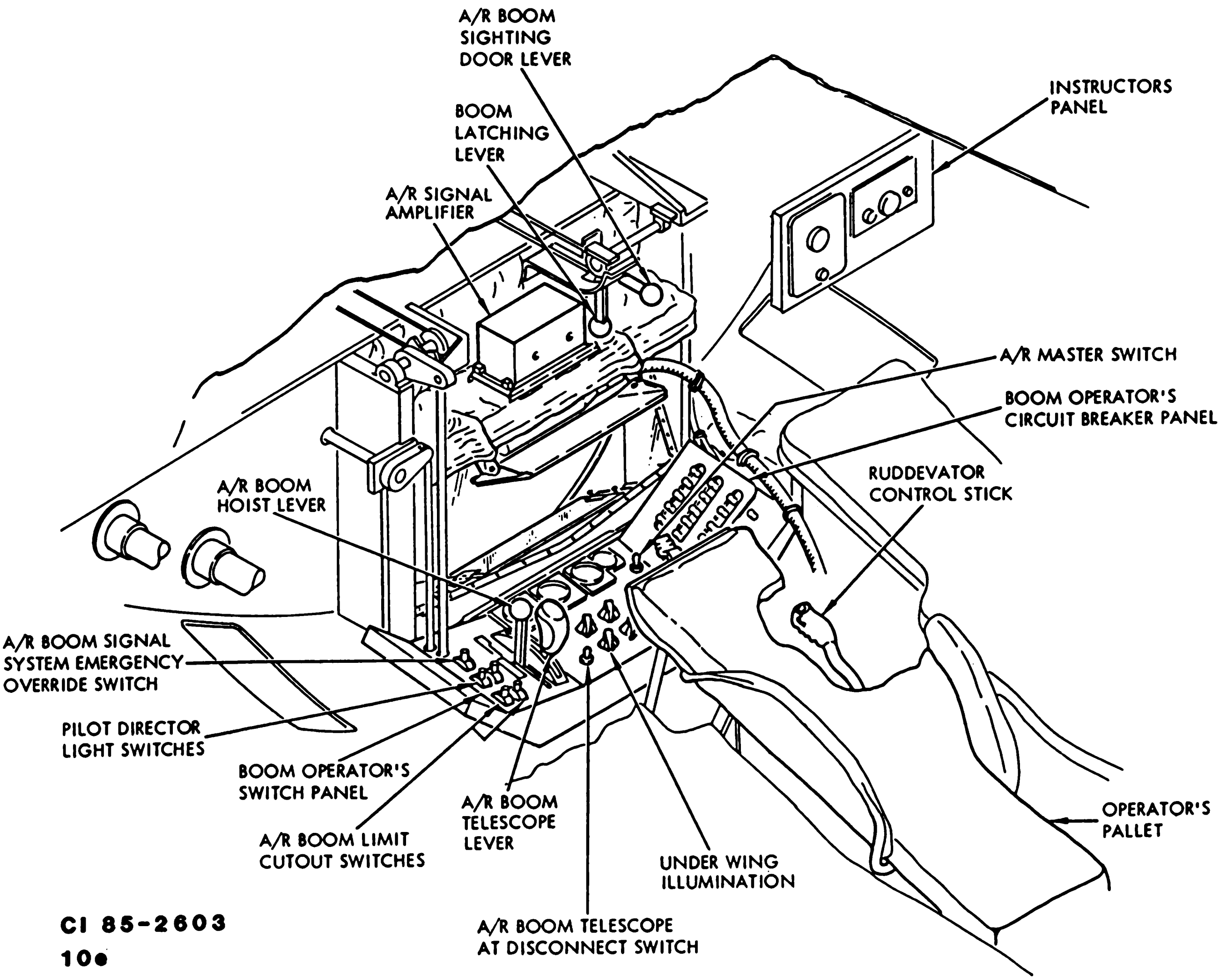


Figure 6–3. Boom operator's compartment.

2. What is used to absorb fuel pressure surges in the boom?

3. What do the roller brackets do?

4. What causes the inner structural tube to telescope?

5. What prevents leakage between the inner and outer fuel tube?

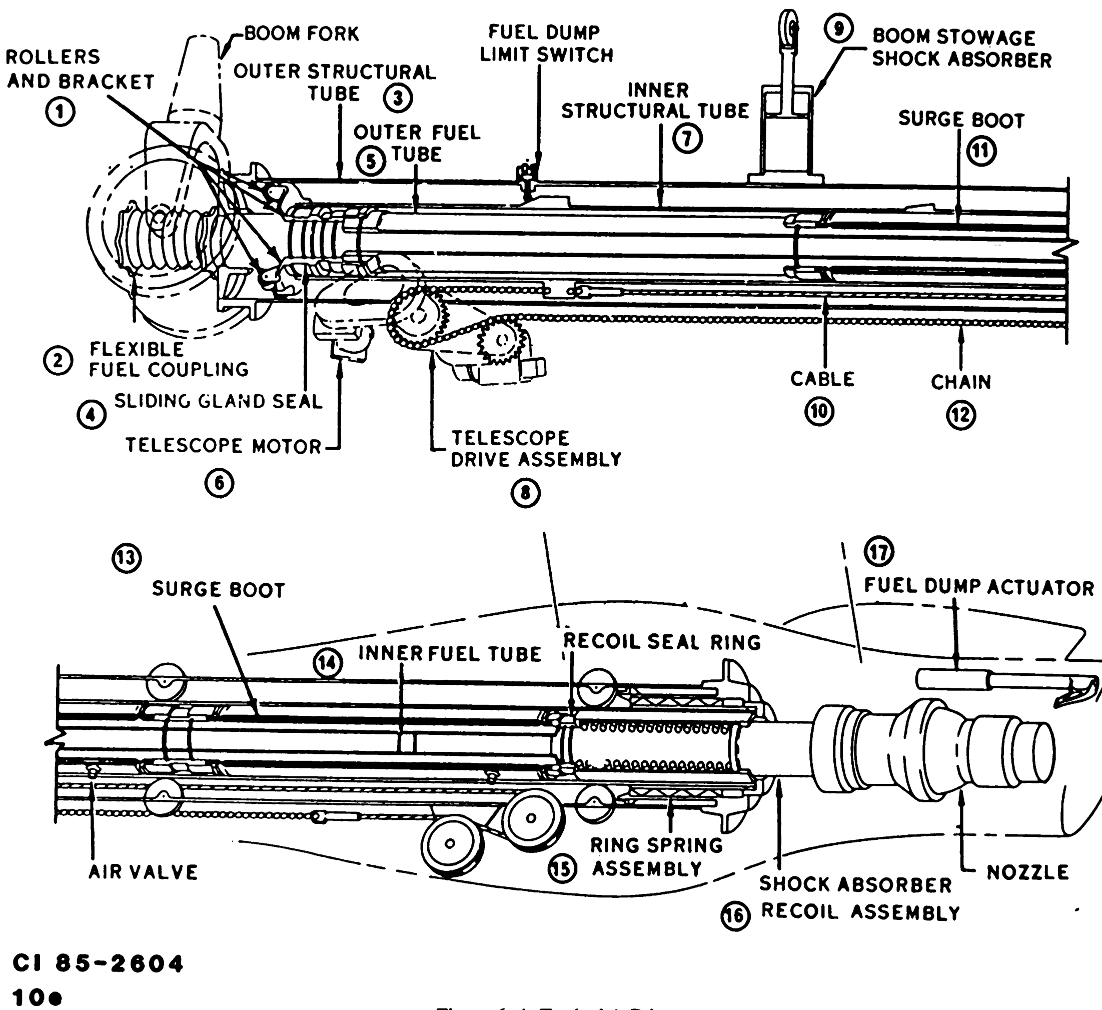


Figure 6-4. Typical A/R boom.

659. Specify how the receiver pilot and boom operator can tell if the aircraft are positioned properly for inflight refueling.

A/R Exterior Lighting System. The receiver pilot director lights and the boom and nozzle marker lights aid the receiver pilot in positioning the aircraft within the safe operating limits of the boom.

Receiver pilot director light system. As we have stated, limit switches in the boom A/R signal system elevation and telescoping control units are connected in the director light circuit. These limit switches turn off or turn on a light or combination of lights in the director light circuit. The result is that the director lights on the underside of the fuselage indicate striped green, green, or red as the boom is positioned. Now look at figure 6-5. This figure illustrates a typical receiver pilot director light system. Observe that the elevation lights consist of five panels with striped green, green, and red colors, and two illuminated lettes ''D'' and ''U,'' for down and up respectively. These letters are at the ends of the row of lights and are on their sides. Now observe the telescoping lights. Note that the colored panels are separated by illuminated white panels. Also note the illuminated letters ''A'' for aft and ''F'' for forward, which are at the ends of the row of telescoping lights. (There are no lights for azimuth position).

When the receiver aircraft is positioned within the red minimum limits of the boom envelope, the receiver and tanker aircraft can make contact (or maintain contact). When the receiver aircraft is attached to the tanker aircraft for inflight refueling, the receiver pilot has to pay particular attention to the director lights. As an example, if the receiver aircraft drops too far behind the tanker aircraft, the ''F'' for forward director light will come on. When this happens, the receiver pilot must increase the speed of the aircraft.

Boom nozzle and marker lights. Boom nozzle and marker lights are mounted in the boom nozzle hood. You can see the locations of these lights in figure 6-5. The two boom marker lights are fluorescent black light lamps. Their ultraviolat rays cause the boom markings to glow during night refueling operations. As shown in figure 6-6, the

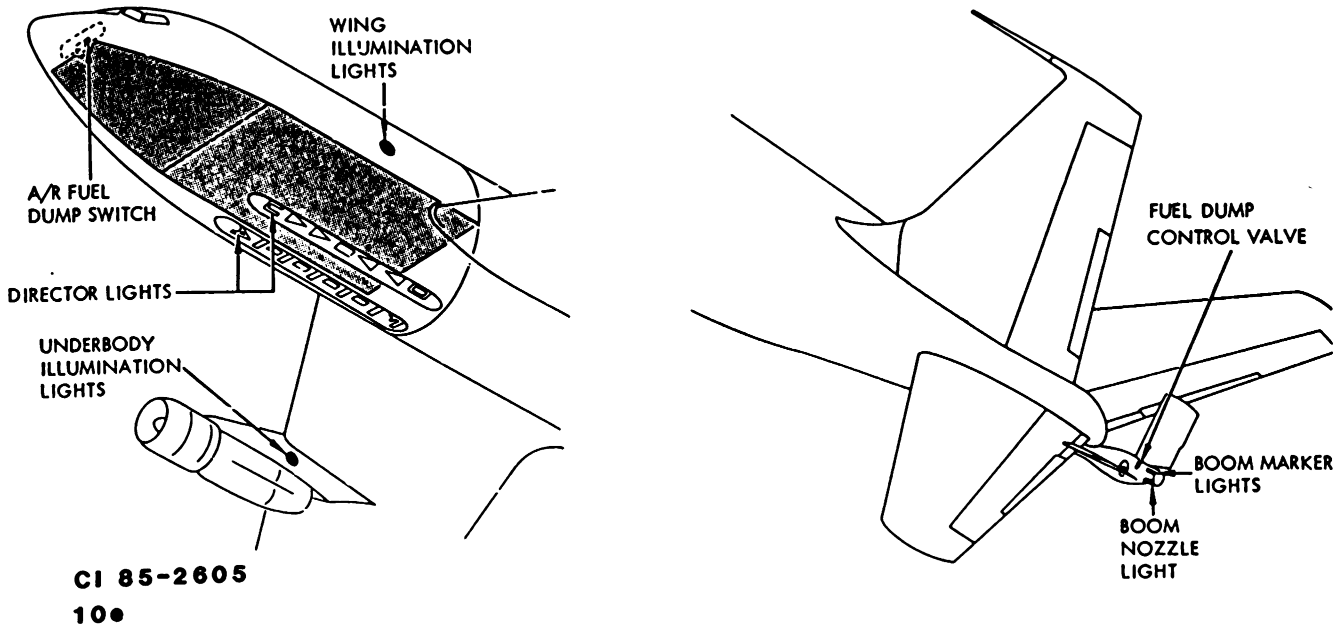


Figure 6–5. A/R exterior lights.

outside surface of the inner structural tube has color markings. These markings are visible only when the boom is extended. They indicate how far the boom is extended. During night refueling, the markings are illuminated by the boom marker lights. As the boom extends, the following markings appear: (1) solid red, (2) red and yellow chevron stripes, (3) solid yellow, (4) green and yellow chevron stripes, (5) solid green, (6) green and yellow chevron stripes, (7) solid yellow, (8) red and yellow chevron stripes, and (9) solid red. As the operator extends the boom, he or she can observe the markings and know how far the boom has extended.

Exercises (659):

1. If the receiver pilot moves out of the safe operating limits when hooked to a tanker aircraft, how will he or she know?

2. How does the boom operator know how far the boom has extended at night?

3. If a receiver pilot that is hooked up to a tanker aircraft notices a red U and A, what should the receiver pilot do?

4. Is the azimuth position of the boom indicated by the tanker pilot direct lights? Explain.

660. Describe or explain the operation of the fuel feed system and its components.

Fuel Feed System. Fuel is supplied to the fuel feed system from fuel tanks in the tanker aircraft. The main tanks and a center wing tank are located in the wings of the aircraft. A forward body tank is located in the fuselage below the cargo deck and in front of the wings. The aft body tank is located in the fuselage below the cargo deck and behind the wings.

In the following discussion, use figure 6-7 to trace the fuel flow from the fuel tanks to the boom.

When the air refueling pump switch (17) is turned on, a solenoid-operated shutoff valve opens to allow hydraulic pressure to flow to the four transfer pumps (3). The pumps are driven by a hydraulic motor. When this happens, fuel for the A/R system is pumped out of the forward tank (2) and aft tank (14) into the air refueling manifold (5). Additional fuel may be transferred into these tanks from the center wing and main tanks (1 and 15) through gravity flow lines. Located between the pumps and the manifold is a check valve (4) and a low-pressure warning switch that causes a warning light to come on when the fuel pressure is low. If the line valve (8) is open, the fuel in the manifold passes through the pressure regulator (9), the flow measuring transmitter (10), and out to the boom.

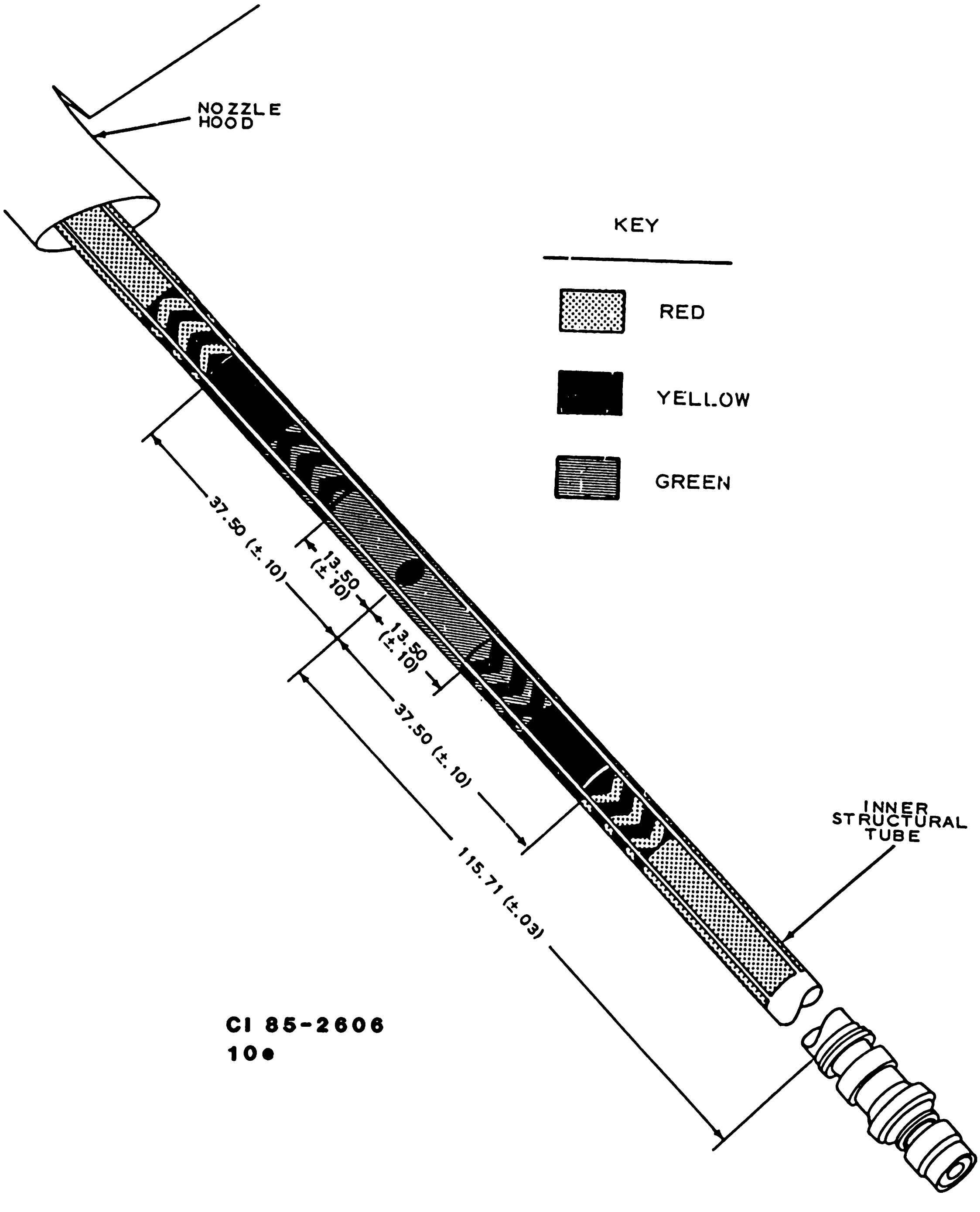


Figure 6–6. Boom markings.

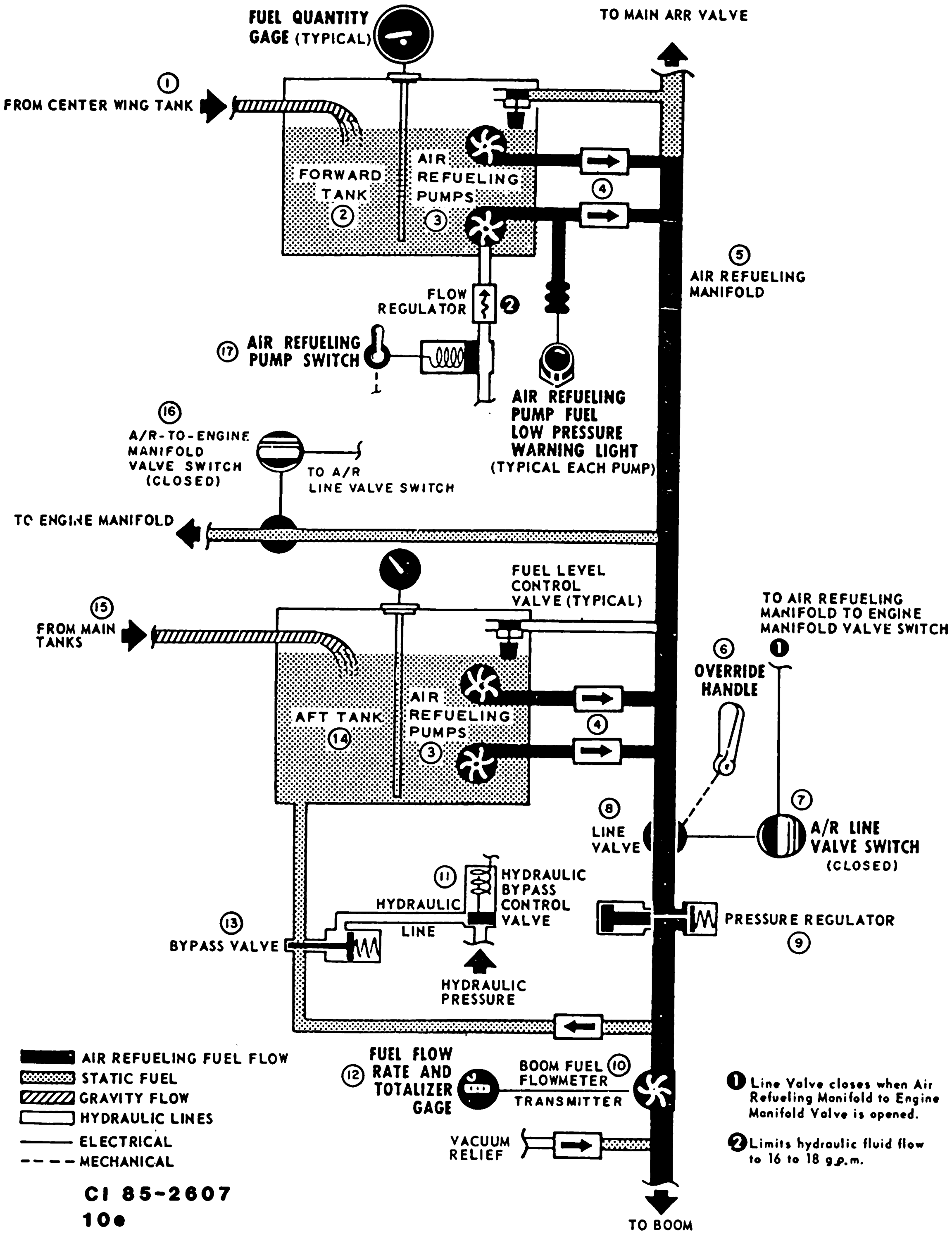


Figure 6–7. Fuel transfer system.

Valves control fuel flow through the system. Fuel flow from the A/R manifold into the aircraft's engines is controlled by the A/R-to-engine manifold valve switch (16). The line valve (8), normally operated electrically through the A/R line valve switch (7), shuts off fuel flow to the A/R manifold and boom. The line valve also has a manual override handle (6) that can be operated to shut off fuel flow to the boom if electrical power is lost. Next, notice the automatic fuel bypass valve (13) in the A/R system. This valve enables fuel trapped in the boom at disconnect to flow back to the aft body tank. Also observe the hydraulic bypass control valve (11). This valve directs hydraulic fluid to open the bypass valve when the A/R boom is being retracted. When the A/R boom is fully retracted, the bypass valve closes. We talk more about this in the following objective.

Now, refer to foldout 11 as we discuss the following components in the boom fuel system. An A/R fuel manifold venturi (narrow portion) is located just forward of the A/R boom. The venturi is installed in the A/R manifold to sense fuel flow. A port at the throat of the venturi senses the fuel back pressure and transmits this pressure through the A/R sensing line restrictor check valve to the fuel pressure regulator. The regulator controls the rate of fuel flow through the boom.

An A/R manifold vacuum relief valve, shown just below the A/R manifold venturi, prevents cavitation in the A/R manifold when extending the boom.

Exercises (660):

1. How is the fuel transferred from the wing tanks to the aft tanks?

2. In what compartments are the hydraulic transfer pumps installed?

3. If electrical power fails, how is fuel stopped from going to the boom?

4. Explain how fuel is pumped from the forward body tank into the boom fuel manifold.

5. What is the purpose of the A/R manifold venturi?

6. What valve enables fuel trapped in the boom at disconnect to flow to the aft body tank?

7. What valve directs hydraulic fluid to the bypass valve when the boom is being retracted?

661. State the purpose and specify the operational features of each system in the boom hydraulic system.

Boom Hydraulic System. This system performs the following six basic functions: (1) opens the boom operator's sighting door, (2) hoists the refueling boom, (3) extends and retracts the boom, (4) operates the fuel bypass valves, (5) opens the boom nozzle poppet valve during fuel dump, and (6) furnishes pressure to the ruddevator power units. Let's see how the system performs these functions. As you read the text, refer to foldout 11 to locate and identify the system units.

Sighting door. The sighting door must be open in order for the boom operator to have a full view of the boom and receiver aircraft. The door is controlled through a manually operated valve, as shown in figure 6-8. Notice that the valve has a lever with OPEN and CLOSE positions. When the sighting door is closed, it provides a smooth aerodynamic surface with the aircraft skin. Also, when the valve is in the CLOSED position, it shuts off pressure to the boom hoist, tension motor, and powered ruddevators. When the control valve is placed in the OPEN position, you direct hydraulic pressure to the sighting door actuator, which lifts a locking pin and the door opens into the fuselage. When the valve is in this position, hydraulic pressure is available to all the other hydraulic subsystems. Figure 6-8 shows the control valve in the CLOSED position. Fluid flows from the pressure line to the actuator.

Ruddevators. The ruddevators provide aerodynamic control of boom elevation and boom azimuth (horizontal measurement from a fixed point, clockwise, around the horizon). When the sighting door control valve is in the OPEN position, the control valve directs pressure to the ruddevator control valve and actuator. See figure 6-9. Movement of the ruddevator control stick positions the ruddevator control valve to direct hydraulic pressure to the actuator to move the ruddevators. As the ruddevators rotate, the housing of the unit, which is connected to the ruddevators, moves relative to the control valve slide. In this manner, the housing serves as the followup that allows the ruddevator to be positioned at any point within its limit of travel.

Boom hoist. The boom hoist control valve (fig. 6-10) controls boom hoist motor operation when raising or lowering the boom. When you hold the boom hoist control lever to RAISE, a piston in the control valve is positioned to direct hydraulic pressure to the raise side of the boom hoist motor. At the same time, the lower side of the boom hoist motor is open to return. When you hold the boom hoist control lever to LOWER, the piston in the control valve is positioned so that the raise, lower, and return ports are interconnected. Thus, the boom lowers because of its weight. A flow regulator in the boom raise line limits the speed of the boom as it lowers. When the boom hoist control lever is in the FREE WHEEL position, system

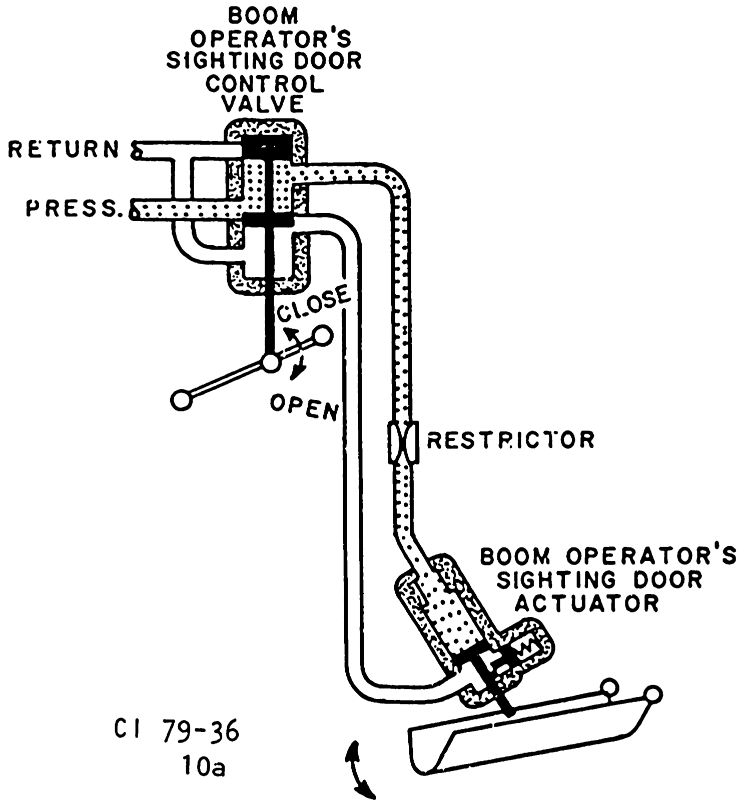


Figure 6–8. Sighting door system.

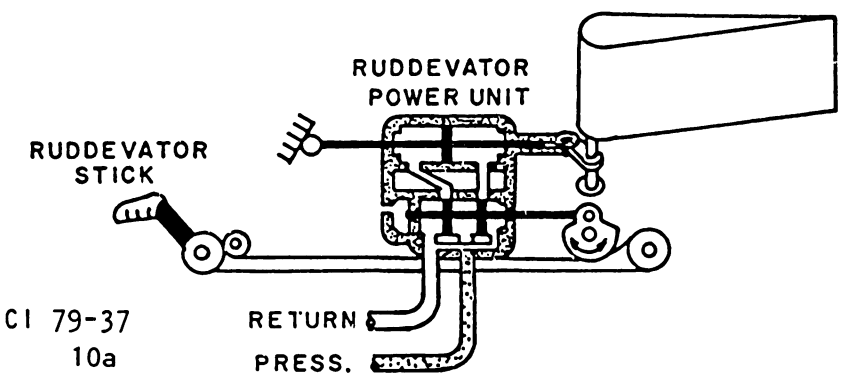


Figure 6–9. Ruddevator system.

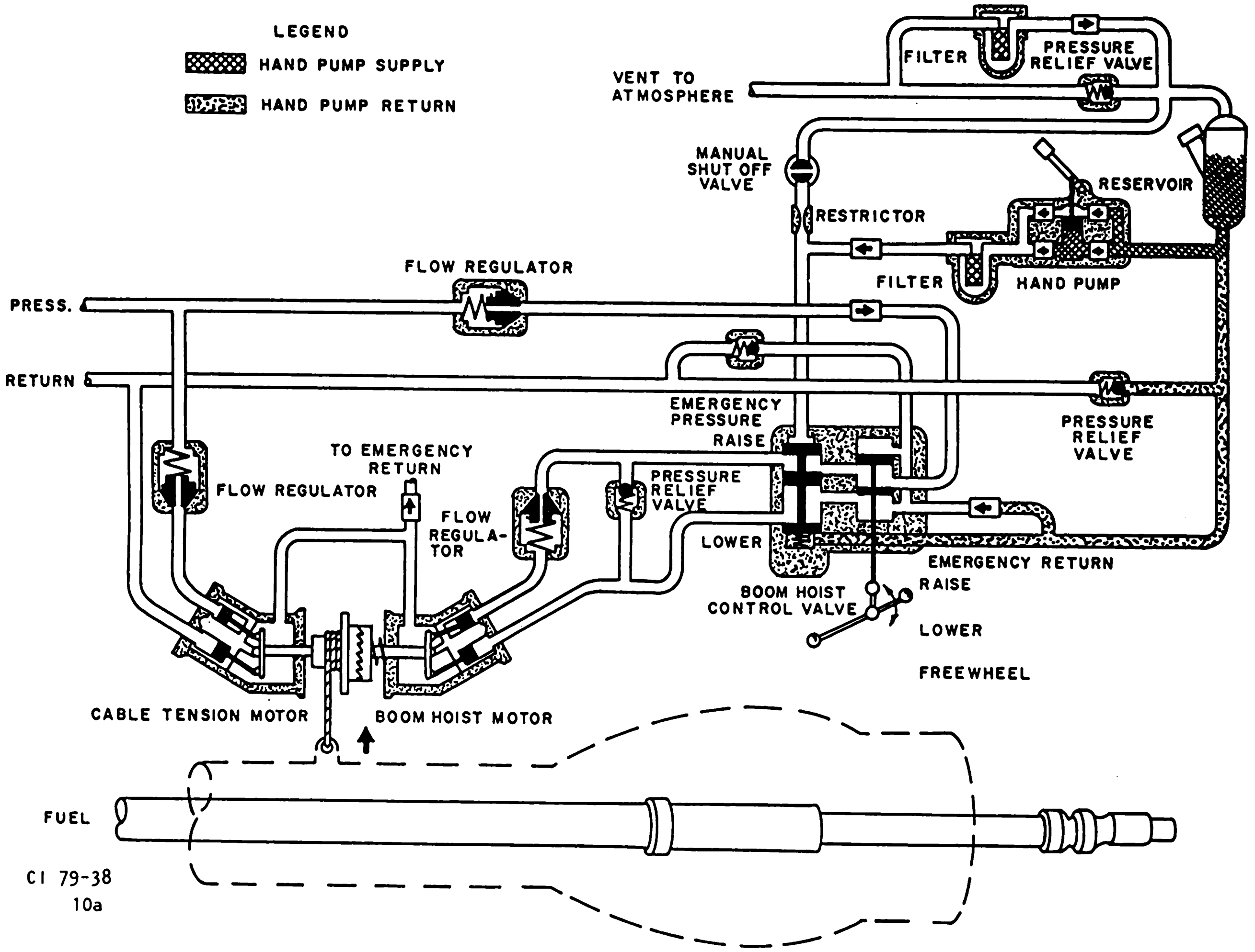


Figure 6–10. Boom hoist system.

pressure is directed to both sides of the hoist motor. This equalized pressure to the motor results in a balanced condition which allows the boom to be aerodynamically flown.

You can also operate the boom hoist motor through an emergency system. During an emergency, the boom is hoisted by pressure supplied by the hand pump located to the upper right of the boom hoist control valve, as shown in figure 6-10. Since there is a possibility of a hydraulic lock in the boom hoist control valve during emergency operation, position the hoist control lever to RAISE before operating the hand pump. As you can see from the diagram, hand pump pressure enters the boom hoist control valve at the emergency pressure port. This pressure moves a shuttle valve, which, in turn, directs the pressure to the raise side of the boom hoist motor. Shuttle valve movements open the emergency return port of the control valve; thus, hydraulic fluid returns to the emergency reservoir. The manual shutoff valve, located above and to the left of the hand pump, must be closed to build up any pressure with the hand pump.

The boom hoist unit consists of four rigidly connected assemblies: The hoist motor, cable tension motor, cable drum, and gearbox assembly. The reversible hoist motor drives a cable drum through the jaw clutch in the gearbox assembly. This causes the cable drum to rotate. During refueling, when the boom is being flown, the tension motor drives the drum to take up slack in the cable. The jaw clutch disengages the hoist motor from the cable drum if the boom is flown to the UP position faster than friction and inertia will allow the hoist motor to turn.

Boom telescoping system. As figure 6-11 shows, pressure is always available through the inflight refueling system accumulator to the boom telescope valve. Notice also that the lever for this valve has RETRACT and EXTEND positions. With the lever in the EXTEND position, hydraulic pressure is directed to the boom telescope hydraulic motor. The motor is attached to a chain and sprocket assembly that will extend the boom. When the control valve is placed in the RETRACT position, the chain and sprocket assembly retracts the boom.

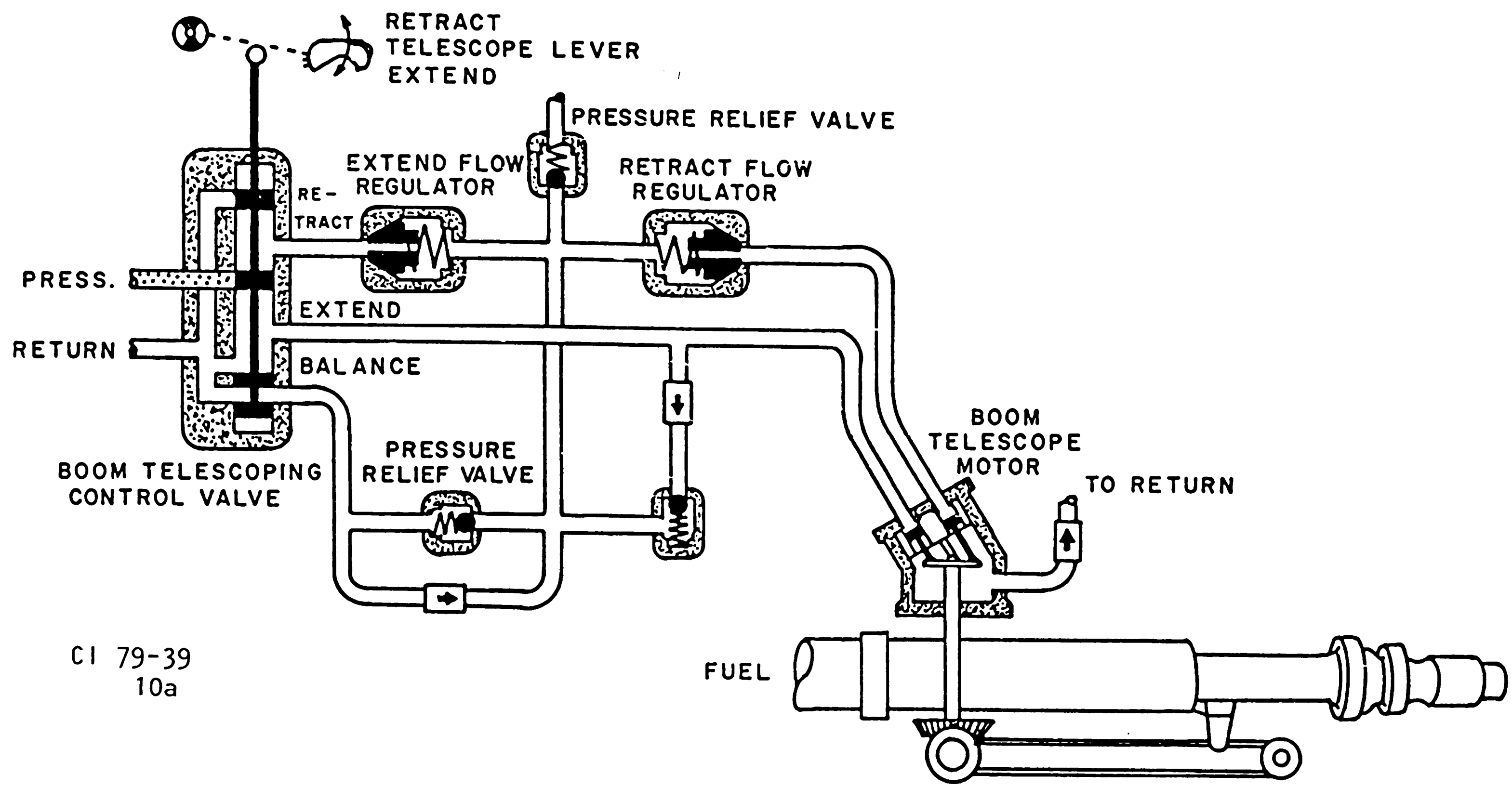


Figure 6–11. Boom telescoping system.

Fuel dump system. The fuel dump system is used to dump fuel overboard in emergency. With the fuel dump control valve deenergized, as shown in figure 6-12, hydraulic pressure is applied to both sides of the fuel dump actuator. The actuator is in the EXTEND position because of the larger area on the extend side of the piston. To dump fuel, the fuel dump switch must be placed to the DUMP position. This energizes the fuel dump control valve, which directs hydraulic pressure to the retract side of the fuel dump actuator. When the actuator retracts, it depresses the check valve on the boom nozzle, which will dump the fuel overboard.

Auto retract control system. Notice the auto retract control valve and the auto retract actuator in figure 6-13. A telescope-at-disconnect switch controls the position of the auto retract control valve. This switch selects the control of the boom at disconnect from the receiver aircraft. In AUTO, the boom automatically retracts when the signal system (you learn more about this later) advances to DISCONNECT. Also observe that the auto retract control valve is shown deenergized. In this control valve position, hydraulic pressure is directed to the bottom side of the auto retract actuator. However, whenever a DISCONNECT signal occurs or whenever the copilot actuates the fuel dump switch, the auto retract control valve is energized. In the energized position, hydraulic pressure is directed to the auto retract actuator to extend it.

Air refueling fuel bypass. Refer to figure 6-14. When you position the boom telescope lever to RETRACT (with the boom extended) or when the auto retract actuator moves to DOWN, the bypass control valve is energized. When the control valve is energized, it permits hydraulic pressure to open the air refueling fuel bypass valve. With the fuel bypass valve open, excess fuel trapped within the boom during retraction flows back to the aft body tank.

An A/R manifold venturi is located just forward of the A/R pressure regulator. The venturi is in the A/R manifold

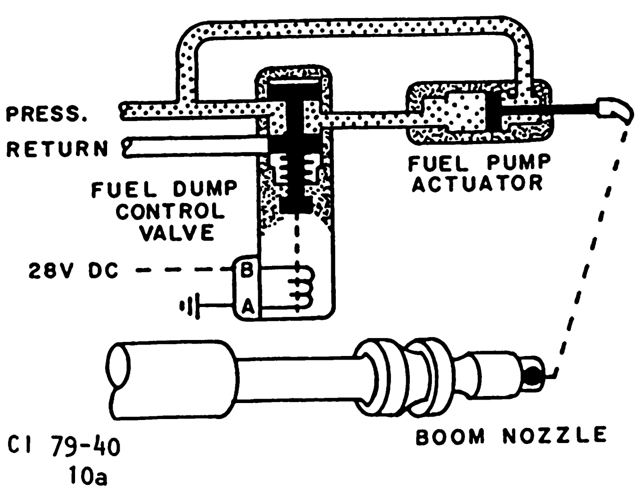


Figure 6–12. Fuel dump system.

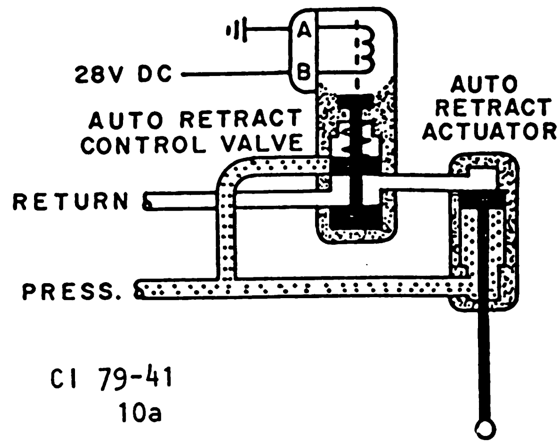


Figure 6–13. Auto retract system.

to sense fuel flow. A port at the throat of the venturi senses fuel back pressure and transmits this pressure through the A/R sensing line resistor check valve to the fuel pressure regulator. An A/R manifold vacuum relief valve prevents a vacuum from forming in the fuel tube as it is extended. The valve will allow atmospheric air to enter, but yet will not allow fuel to flow out.

Exercises (661):

1. Which systems of the boom hydraulic system are affected by closing the sighting door?

2. List the hydraulic subsystems of the boom hydraulic system.

3. How is fuel dumped overboard from the boom nozzle?

4. What is the purpose of the air refueling fuel bypass system?

5. To what system will hydraulic pressure be applied when the sighting door control valve is in the OPEN position?

6. What is the purpose of the ruddevators?

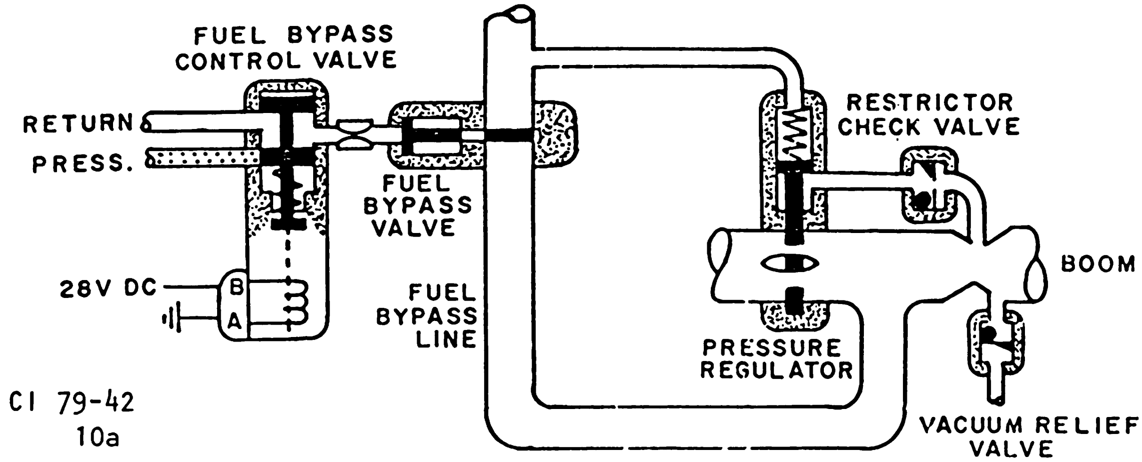


Figure 6–14. Fuel bypass.

7. What happens when the ruddevator control stick is moved?

8. What does the tension motor do?

9. In what position is the boom hoist control valve when the raise, lower, and return ports are interconnected?

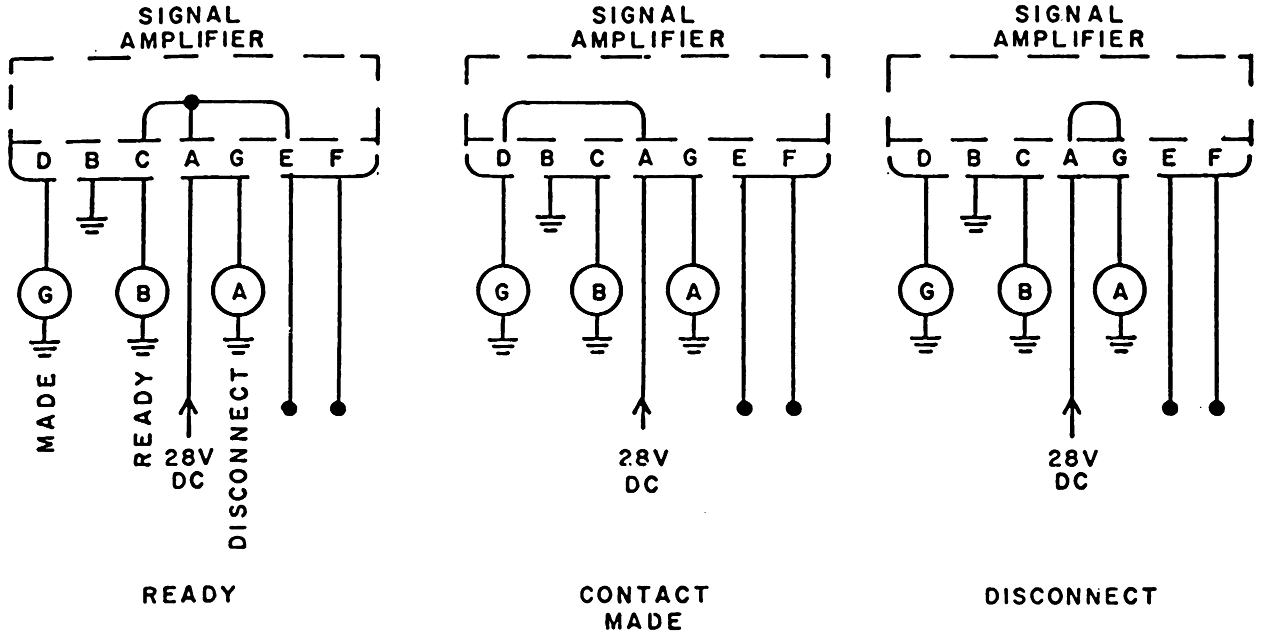
662. State specified construction and operational features of the A/R signal system.

A/R Signal System. A circuit diagram of a typical A/R signal system is shown in foldout 11. This system automatically controls the operation of the hydraulic system for the READY, MADE, AND DISCONNECT conditions of the boom during refueling. Notice in foldout 11 that the system consists of both hydraulic and electrical components. As we discuss each of the items, locate it on the foldout so that you will have a general idea where and why it is located in the system. The hydraulic-electrical components of the A/R signal system include the auto retract control valve, fuel bypass control valve and fuel dump control valve. These items were discussed earlier in this chapter. The electrical components of the A/R signal system include the fuel dump switch (1), fuel dump relay (2), telescope-at-disconnect switch (3), signal amplifier (4), the azimuth limit switches (5), the elevation limit switch (6), the telescope limit switch (7), the A/R master switch (8), A/R reset switch (9), contact made relay (10), emergency override switch (11), an A/R test switch (12), and a disconnect switch (13). Three other items that we will discuss are the boom signal coil (14) located on the boom nozzle, the fuel bypass control valve switch (15) located just above the telescope lever, and the fuel dump limit switch (16) located just above the boom, next to the boom hoist cable. The signal amplifier (4), which is the heart of the air refueling system, is actually an electronic three-position switch. Whenever an electrical signal is sent to the amplifier, it switches to the next position. The three positions and the order of sequence are READY (this is the normal position to which the signal amplifier returns when all power is removed), CONTACT MADE, and DISCONNECT. To understand this better, take a look at figure 6-15 as we discuss the operation of the signal amplifier. When power is turned on, it flows to pin A of the amplifier. Notice that it tee's off and flows to pin C, which turns the blue READY light on, and to pin E. When the boom makes contact with the receiver aircraft, a signal is sent to pin F which flips the power to pin D. This will turn the green light on, indicating that contact is made with the receiver aircraft. If for some reason another signal is received through pin F (from a number of signals, which we will talk about later) the amplifier will flip from pin D to pin G. This will turn the amber light on, indicating DISCONNECT.

Now that you have a basic understanding of the signal amplifier, let's refer to foldout 11.

The A/R signal system for the tanker operates in conjunction with the receiver signal system to automatically control the hydraulic and fuel system during refueling. Signals originating in either signal system are transmitted to the other signal system through the signal coils (14) in the boom nozzle and nozzle receptacle.

Ready to make contact. To initiate the READY condition (before making contact with the receiver aircraft) the boom operator positions the A/R master switch (8) to ON. When this happens, 28 volts DC power flows through



NOTE

WHEN SIGNAL IS RECEIVED THROUGH PIN F THE AMPLIFIER WILL ADVANCE TO THE NEXT CONDITION.

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Figure 6–15. Signal amplifier circuitry.

the boom operator's circuit breaker panel, through the A/R reset switch (9), through the center contact of the emergency override switch to pin A of the signal amplifier (4). From there it tee's off and goes to both pin C and pin E. As power flows through pin C it turns the READY light on. Notice that the power through pin E goes to the A/R test switch (12). Since the switch is not pushed in, the power from pin E simply stands by.

Contact is made. When contact is made with the receiver aircraft (MADE condition), the boom nozzle actuates a switch in the receiver receptacle. As a result, a MADE signal is sent through the signal coil (14) to pin F of the amplifier (4). This signal actuates the signal amplifier, to direct power to pin D. This causes the following functions to take place:

- The MADE light illuminates.
- The contact made relay (10) is energized.

When the contact made relay (10) is energized, it completes a circuit from the boom operator's circuit breaker panel to the envelope limit switches (5, 6, and 7). These limit switches operate to automatically disconnect the boom whenever it goes outside the operating envelope limits (safe limits of operation). The boom envelope limits the movement up and down (elevation), forward and aft (telescoping), and horizontally from side to side (azimuth).

Disconnecting from the receiver. When refueling is completed or must be stopped for any reason, a DISCONNECT signal is sent to the amplifier through pin F. A DISCONNECT signal may come from any one of the following sources—the azimuth, telescoping, or elevation limit switches—if the amplifier override switch (11) is in the NORMAL position. Disconnect signals may also come from the boom operator's disconnect switch (13) or from the receiver aircraft through the signal coil (14). After a disconnect signal is received, the amplifier flips over to direct power to pin G. Power from pin G then flows through the bottom contact of the emergency override switch (11) to turn on the DISCONNECT light. If the telescope at disconnect switch (3) is in the AUTO position, power flows through it to the fuel dump relay (2) to the auto retract control valve. The control valve when energized directs hydraulic fluid to extend the auto retract actuator. The retract actuator will position the telescope control valve to route hydraulic fluid to retract the boom. It also causes the fuel bypass control valve switch (15) to move to the closed position. This completes the circuit from the boom

operator's circuit breaker panel, through the fuel bypass control valve switch (15), through the top contact of the fuel dump relay (2), to the fuel bypass control valve and then to ground of the fuel dump limit switch (16). With this circuit completed, the fuel bypass control valve will actuate and open the fuel bypass valve. This will allow the fuel in the boom to return to the aircraft fuel tanks, as the boom is retracted.

Fuel dump control circuit. Now that we have a good idea of what transpires during the normal operation of the inflight refueling boom system, let's see how the fuel dump circuit operates. First, though, why would it be necessary to dump the fuel in the tanker aircraft? This is a good question. It might be that during the flight an emergency might arise which would prevent you from making your mission. The fuel dump system then would be used to get rid of this fuel in order to land the aircraft. Let's assume that an emergency exists and you need to dump the fuel overboard. By actuation of the fuel dump switch (1), a complete circuit is made from the fuel dump circuit breaker to the fuel dump relay (2). The relay pulls all the contacts down. With all the contacts down, notice that power can move through the bottom contact to the auto retract control valve. As you can see, by actuation of the fuel dump switch, the A/R signal system has been overridden. If the boom is extended, the auto retract control valve and the fuel bypass control valve are energized through the fuel dump limit switch (16) and fuel dump relay (2). When energized, these two valves open the fuel bypass valve and retract the boom (but do not stow it). As the boom reaches within 7 inches of full retract, the boom causes the fuel dump limit switch (16) to actuate. Actuation of this switch makes a complete circuit from the fuel dump switch (1) through the top contact of the fuel dump limit switch (16) to the fuel dump control valve. The fuel dump control valve applies hydraulic fluid under pressure to the fuel dump actuator. This allows the actuator to retract, which depresses the poppet valve in the boom nozzle. The fuel can then be dumped overboard. If normal electrical power fails, the aircraft has provisions for using battery power to dump fuel by emergency means.

Exercises (662):

1. How are electrical signals transferred from one aircraft to another during hook up?

2. When power is turned on, what position light should come on?

3. If the receiver pilot moves out of the envelope, what will automatically happen?

4. How far, within full retract, must the boom reach before the fuel dump limit switch in the boom will be actuated to energize the fuel dump control valve?

5. List at least three ways that a disconnect signal can be initiated.

6-2. Air Refueling Receiver System

The air refueling receiver system is installed on aircraft to provide additional load and distance capabilities. The air refueling receiver system, as covered in this section, is referred to as the air refueling receiver, with an abbreviation of "ARR." The ARR system includes the slipway doors air refueling receiver receptacle, fuel manifold system, hydraulic system, and electrical system. These systems operate, control, and give indications of operation. In this section we talk about the construction and operation of these systems.

663. Specify the constructional and operational features of the air refueling receiver system.

Construction of the ARR System. On a representative aircraft, two hydraulically operated slipway doors are located on top of the fuselage, as shown aft of the pilot's compartment. When the slipway doors are open, they provide an entrance to the ARR receptacle. Let's talk about the three systems (fuel, hydraulic, and electrical) that make up this ARR system.

Fuel system. The first item in the fuel system is the receptacle itself. This item serves as an interconnect between the tanker boom and the receiver manifolds. See figure 6-16. It is basically a quick disconnect, acting as the female half, while the boom nozzle is the male half (see foldout 12). The ARR fuel manifold is a 4-inch fuel tube that connects the ARR receptacle to the main fuel valve. Located in the fuel tube is a pressure switch that senses the amount of fuel pressure in the tube. The main fuel valve is a motor-operated shutoff valve. It can be operated to open or close the fuel line.

Hydraulic system. The ARR hydraulic system operates the slipway doors and the ARR receptacle toggles. It is comprised of control valves, shuttle valves, and actuators.

a. Slipway door control valve. The slipway door control valve is a solenoid-actuated hydraulic valve that controls the flow of hydraulic fluid to the slipway door actuators. This causes the slipway doors to open or close, depending on which solenoid is energized.

b. Slipway door shuttle valve. The slipway door shuttle valve is located in the line between the slipway door actuator and the control valve. When the ARR slipway doors are positioned to OPEN, hydraulic pressure moves the shuttle to close off the door line. This action allows the door close line between the shuttle valve and actuator to be

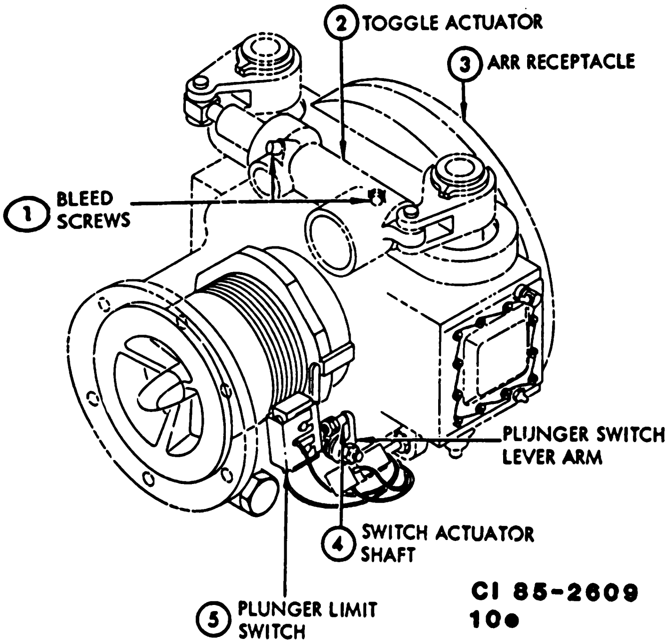

Figure 6–16. Air refueling receiver receptacle.

pressurized. Since both the open and closed line of the actuator are pressurized, the door will open due to the larger area on the door open side of the actuator piston.

c. Slipway door actuators. Two hydraulic actuators open or close the slipway doors. When the slipway doors are closed, the piston is retracted in the actuator and locked by an internal locking mechanism. During the door open cycle, hydraulic pressure forces the piston out of the locking detent and allows the piston to extend to the DOOR OPEN position.

d. Toggle control valves. The toggle control valves are solenoid-actuated and control the flow of hydraulic fluid to the air refueling receptacle toggle actuator. When the toggle control valve is not energized, the return port is open to release pressure from the "latched" port of the toggle actuator.

e. The toggle actuator. The toggle actuator is a double-acting hydraulic cylinder mounted over the air refueling receptacle for actuation of the toggles. Arms, fastened to both the piston and cylinder ends of the actuator, rotate two shafts to which the toggles are attached. The toggle actuator piston incorporates a spring-loaded ball relief valve, which bypasses fluid from the retract side if pressure becomes excessive on the pull-away of the air refueling nozzle from the receptacle.

f. The ARR accumulator is a 25-cubic-inch capacity hydraulic accumulator. It is located in the ARR hydraulic system to absorb hydraulic surging caused by the movement of the toggle actuator during emergency breakaway. An air pressure gage on the accumulator provides a means of measuring the 1000 psi air preload or the total pressure in the accumulator.

ARR electrical system. The electrical system controls the refueling sequence and indicates to the pilot or copilot the sequence condition of the system. The system consists of a signal amplifier, receptacle induction coil, solenoid-operated hydraulic control valves, system switches, ARR signal lights, and selected electrical wiring connecting the components.

The signal amplifier, which is the heart of the air refueling system, is actually an electronic three-position switch. Whenever an electrical signal is sent to the amplifier, it switches to the next position. The three positions and the order of sequence are READY (this is the normal position to which the signal amplifier returns when all power is removed), CONTACT, and DISCONNECT.

ARR system operation. With the master refuel switch in the ON position, the slipway doors CLOSED and LOCKED light will come on. When the normal slipway door control switch is placed in OPEN and the signal amplifier power switch is in the NORMAL position, power is supplied to the open solenoid of the normal slipway door hydraulic control valve. This causes the slipway door control valve to direct pressure to both sides of the slipway door actuators. The doors will open because of the large area on the open side of the piston. Hydraulic fluid is also admitted to the UNLATCH port of the toggle actuator, causing the piston to retract and unlatch both toggles. As the slipway doors open, DOOR CLOSED limit switches will actuate and the slipway doors CLOSED AND LOCKED light will go out. The signal amplifier, when energized, supplies voltage to the slipway DOOR OPEN limit switches, to the normally open plunger limit switch. When the doors reach the fully OPENED position, the slipway door open limit switches will actuate and cause the READY light to come on.

When the tanker boom nozzle seats in the receptacle, the nozzle actuates the plunger limit switch, completing the circuit of the signal amplifier to the hydraulic toggle latching control valve and to the CONTACT light. As the toggle shafts rotate to the boom latched position, the toggle limit switches are actuated. As a result, power is supplied on the amplifier in the CONTACT condition, causing the ready light to go out. In the CONTACT condition, the signal amplifier supplies voltage to one toggle limit switch and to the CONTACT light.

Disconnect signals to the signal amplifier originate when any one of the following conditions occurs:

- Actuation of the autopilot and ARR disengage button on the pilot's or copilot's control wheel.
- Actuation of a disconnect signal by the tanker boom operator.
- Excessive fuel pressure in the ARR fuel manifold, causing the pressure disconnect switch to actuate.
- A break in contact between the boom nozzle and the receptacle, causing the toggle shafts to rotate and actuate the toggle limit switches to the unlatched position. This completes a disconnect signal to the signal amplifier.
- Excessive movement of either the receiver or the tanker airplane causes the tanker boom to exceed envelope limits. In this situation, a disconnect signal

is initiated by the tanker airplane signal system. Disconnect signal circuits of the receiver and tanker airplanes are interconnected by induction between the induction coils in the boom nozzle and the air refueling receptacle.

When the disconnect signal is received at the signal amplifier, the amplifier is placed in a DISCONNECT condition and the disconnect light will come on. Power is removed, deenergizing the normal toggle control valve, and the contact light goes out. With the toggles released, the disconnect signal, transferred to the tanker through the induction coils, causes the tanker refueling boom to retract and the physical disconnect is completed. Momentarily, pressing the signal amplifier reset button on the air refueling panel removes power from the signal amplifier and places the amplifier in the READY condition. The amber DISCONNECT light will go out and the READY light will glow.

After air refueling is completed and a disconnect has been accomplished, the slipway doors are closed by placing the normal slipway door switch to CLOSE. The DISCONNECT amber light will go out. When the doors close, the door-closed limit switches actuate to energize the slipway door relay, and, as a result, the slipway door CLOSED AND LOCKED light comes on. The energized slipway door relay opens the holding circuit for the normal air refueling relay and this deenergizes the ''close'' solenoid of the slipway door control valve. When the master refuel switch is moved to OFF, power is removed from the air refueling control panel and the slipway door CLOSED AND LOCKED light goes out. The signal system components are protected by circuit breakers on the switched DC circuit breaker panel.

Exercises (663):

1. Name the three systems of the ARR system.

2. What connects the ARR receptacle to the main fuel valve?

3. Even though hydraulic pressure is sent to both the open and closed sides of the slipway doors, why does it open?

4. Why does the toggle actuator have a spring-loaded relief valve?

5. What are the three positions of the signal amplifier?

6. When the slipway doors first start to open, what indication should you get?

7. List the conditions that would cause the A/R boom to disconnect.

8. After automatic disconnect, what must be done to place the system back to the READY condition?

6-3. Maintenance of Air Refueling System

The maintenance that you perform on the air refueling system includes the day-to-day tasks that are necessary to keep the equipment in top working order. These tasks include an operational check of the system, removal and installation of system units, repairing components, and servicing the system. Let's discuss the operational check of the system first.

664. Specify why and when operational checks are performed, and why specific steps are required.

Operational Check. Perform an operational check of the boom hydraulic system to insure that all system components are functioning properly. The portions of the check that you perform may include all steps of the check or only certain steps. This depends on the maintenance that has been performed on the system. For example, when the boom on an aircraft has been changed, you perform all steps of the operational check. On the other hand, when you change a component or make an adjustment in the system, you perform only those steps that are necessary to insure the system is functioning properly. Since there are times when all steps of the boom hydraulic system check are performed, let's discuss the complete check.

Figure 6-17 is a check sheet similar to the one included in the TO. Study this figure and see what the check involves. The first part of the check, 1 and 2 in the Action column, is performed with the system unpressurized. The second part of the check, 3 through 31 in the Action column, is performed with the system pressurized. Thus, when performing the second part of the check, apply electrical power, as stated in step 22.

Certain tools and equipment are required to perform the boom hydraulic system operational check. The required tools and equipment are identified as we review figure 6-17. For example, step 8 tells us we need an A/R sling assembly, step 17 indicates we need a spring scale, and the caution following step 18 tells us we need a padded maintenance stand. Also, step 22 indicates we need a ground power unit to supply electrical power. And, of course, we need a hydraulic power unit to supply the hydraulic pressure.

As you study figure 6-17, pay particular attention to the cautions and notes. The cautions are provided to prevent

ACTION	NORMAL RESULT
Condition: System Unpressurized	
1. Move boom hoist lever to LOWER and release.	1. Lever returns to "HOLD" unassisted.
2. Move boom hoist lever to RAISE without engaging the raise detent and release.	2. Lever returns to "HOLD" unassisted.
Condition: System Pressurized	
3. Position boom operator's sighting door lever to OPEN.	3. Sighting door opens without binding or sticking.
4. Position sighting door lever to CLOSE.	4. Sighting door closes without binding or sticking and fairs with aircraft fuselage.
5. Position sighting door lever to OPEN, boom hoist lever to RAISE, and boom latching lever to UNLATCH. Then position the boom hoist lever to LOWER.	5. Boom hoist cable lowers at a rate of 6 to 12 inches per second. CAUTION: Do not let the boom fall and strike the ground.
6. Position boom hoist lever to RAISE.	6. Boom hoist cable raises at rate of 1 to 2 inches per second.
7. Lower boom to horizontal position and move hoist lever to hold.	7. Boom lowers to and remains in horizontal position.
8. Install boom A/R sling assembly, then move boom hoist lever to FREE WHEEL.	8. Boom can be moved up and down and to either side. CAUTION: Never position hoist lever to FREE WHEEL with the boom unlatched unless the boom is supported.
9. Pull hoist cable sideways.	9. Cable tension motor exerts a force of about 90 pounds on the cable.
10. Pull cable sideways.	10. Cable extends.
11. Reduce pull on cable.	11. Tension motor rewinds cable.
12. Move control stick through full travel in both azimuth and elevation directions.	12. Control stick moves easily with one hand through full travel, and ruddevators follow stick movement without noticeable drag. NOTE: Control stick travel with hydraulic power off will be difficult. This is normal and not cause for system rejection.
13. Move control stick to FULL DOWN (0° azimuth) and slowly release.	13. Stick returns to less than 3 inches from the stowed position.
14. Move control stick to FULL UP (0° azimuth) and slowly release.	14. Stick returns to less than 3 inches from the stowed position.
15. Move control stick to FULL RIGHT (0° elevation) and slowly release stick.	15. Stick returns to less than 3 inches from the stowed position.
16. Move control stick to FULL LEFT (0° elevation) and slowly release.	16. Stick returns to less than 3 inches from the stowed position.
17. Measure force required to move control stick with a spring scale placed at end of stick.	17. Breakaway force from neutral in a side direction is 5.5 pounds. Force required to move the control stick to the upper stop (0° azimuth) is within 6-14 pounds. The force to the lower stop (0° azimuth) is within 28-45 pounds. The force to the right and left stops (at stowed elevation) is within 10-18 pounds.
18. Remove boom sling assembly, lower boom to about 10 degrees below horizontal, and position hoist lever to HOLD. CAUTION: Place padded maintenance stand under boom before checking A/R boom emergency hoist system. Stand should be as close to boom as possible to prevent damage if boom drops.	18. Boom lowers to about 10 degrees below horizontal and stops.
19. Move boom sighting door lever to CLOSE, boom hoist lever to RAISE, and boom emergency hoist manual shutoff valve to EMERGENCY BOOM HOIST.	19. Sighting door closes, pressure to boom system stops, hoist control valve is positioned to raise, and boom hoist shutoff valve is closed.
20. Operate the hydraulic hand pump.	20. Boom is raised fully in about 70 pump strokes.
21. Position boom latching lever to LATCHED, boom hoist lever to HOLD, sighting door lever to OPEN, and boom emergency hoist manual shutoff valve to NORMAL.	21. Boom is latched in stowed position, boom hoist control valve positions to hold, sighting door opens and pressure is applied to system, and the manual shutoff valve opens.
Condition: Electrical Power ON	
22. Connect external power and turn A/R master switch ON.	22. Electrical power is supplied to the system.
23. Move boom telescope lever to maximum EXTEND.	23. Boom extends smoothly and gains speed as lever is advanced to full extend position. Boom travels to full extension in 4.5 to 6.5 seconds.
24. Move boom telescope lever to RETRACT.	24. Boom retracts smoothly.
25. Extend boom about 10 feet with boom telescope lever and allow boom telescope lever to center. Then grasp boom nozzle and pull to extend boom.	25. Boom does not extend.
26. Push on boom nozzle to retract boom.	26. Boom does not retract.
27. Check that A/R pump switches are OFF, move fuel dump switch to FUEL DUMP.	27. Boom retracts fully and fuel dump actuator depresses boom nozzle poppet valve.
28. Return fuel dump switch to NORMAL.	28. Fuel dump actuator extends and poppet valve closes.
29. Disconnect electrical connector from auto retract control valve. Then hold boom telescope lever in RETRACT and position the fuel dump switch to FUEL DUMP.	29. Fuel dump actuator retracts and opens boom nozzle poppet valve.
30. Hold boom telescope lever in RETRACT and return fuel dump switch to NORMAL.	30. Fuel dump actuator returns to normal.
31. Install the electrical connector to the auto retract control valve.	
Return controls to normal positions. Position boom sighting door lever to CLOSE, and place A/R master switch to OFF.	

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Figure 6–17. IFR check sheet.

damage to equipment. Notice the caution below step 8 in the Normal Result column. This reminds you that the boom could drop to the ground and be damaged. Be sure to observe all cautions. The notes are provided to give extra information on specific steps or results of the operational check. An example of a note follows step 12 in the Normal Result column. Other information pertaining to the check may appear in the form of warnings. Although a warning isn't shown in figure 6-17, warnings are applicable to some boom hydraulic system checks. For instance, certain types of aircraft radio equipment must be turned off before the check is performed. If radio equipment is operated during the check, a dangerous RF voltage may be induced into the boom. This voltage would endanger personnel performing the check. Be sure to observe all warnings.

Before you perform the operational check on a specific aircraft, check the procedure in the applicable technical order. Remember that procedures differ on some aircraft and you might damage the boom or injure personnel if you follow incorrect procedures.

Exercises (664):

Referring to figure 6-17, item 18, why does it require that a padded maintenance stand be used to support the boom?

1. Explain why the complete operational check of the boom system is not necessary when the hydraulic accumulator has been removed and replaced.

2. Why is it necessary to turn off certain types of aircraft radio equipment before an operational check is made?

3. Refer to step 17 of figure 6-17. Why is a spring scale necessary?

665. Stipulate some of the items checked during an inspection and then specify general information pertaining to the removal and installation of the A/R system components.

Air Refueling System Inspection. The A/R system is inspected in accordance with the –6 TO or workcards. The A/R system consists of hydraulic, fuel, electrical, and mechanical systems; each should be inspected. To give you some idea on the items that should be checked, we have separated the A/R system into individual systems. Check the hydraulic system for leaking, chaffed, or otherwise damaged lines or hoses. Inspect the units themselves for leakage and security of mounting. Some items like the accumulator should be checked to insure proper servicing. Check also the items in the fuel system for leakage, security of mounting, and in the case of the nozzle, for damage. Check the fuel surge boot for servicing. Check the electrical system for loose wires and cuts in the insulation; the signal coil on the nozzle for corrosion; the mechanical components, cable, pulleys and levers for damage, binding, and proper operation.

This of course is just a sample of items that should be checked during the inspection of the boom system. Any items that are found defective should be written up for corrective action. In many cases the items will have to be removed and replaced.

Removal and Installation of Components. Removal and installation, or replacement, of units in the boom system may take a major part of your time until you become proficient in performing the task. Procedures for removing and installing specific system units are included in technical orders. However, some general information applies when removing and installing any unit.

First, you know that safety is very important when any unit in the system is removed or installed. Safety practices include special precautions to keep you from damaging equipment or injuring personnel. Some of these precautions are:

a. Depressurize the system before removing a unit. If the air refueling hydraulic system is not depressurized, the boom may be accidentally extended, and injury to personnel and equipment could result.

b. Turn off any radio equipment that might induce an RF voltage in the boom. It is possible for RF voltages to ignite combustible vapors.

c. Observe the NO SMOKING signs. Doing so reduces the danger of igniting fuel vapors that might be present.

d. Plug or cap open ends of tubing or lines. Doing so keeps foreign matter out of the system.

e. Place a stand under the boom where the ruddevators connect. If the stand is positioned in any other area, the boom fairing will be crushed. (This precaution is required when the boom is lowered to remove a unit).

Second, you know that tools and equipment are required for removing and installing a unit. But what tools and equipment are required? Usually you need only the common handtools from your toolbox. However, when additional special tools and equipment are needed, you can identify them as you check the technical order procedure for removing and installing the unit.

Exercises (665):

1. List two items hydraulic hoses would be inspected for.

2. Why is it necessary to depressurize the system before removing any of the units?

3. What should a cable be checked for?

4. After removing a hydraulic component, caps and/or plugs should be put over all the open parts and tubing. Why is this necessary?

666. Identify the steps to use when troubleshooting an A/R system and then identify the probable causes for given symptoms and conditions.

Troubleshooting. The ability to find the cause of a trouble is one of the differences between an average repairman and a top repairman. If you expect to get to the "top of the heap," you must be able to troubleshoot. You should adopt some orderly system of trouble analysis. The problem-solving method is one of many systems. It consists of the following steps: (1) become aware of the problem; (2) investigate and research; (3) eliminate possibilities; (4) isolate the trouble; (5) prove your conclusions; and, finally, (6) correct the trouble.

Become fully aware of the trouble. That is, get a clear idea of the problem. Read the writeup, if there is one, and talk to the person who discovered the trouble. Perform as complete an operational check as the circumstances permit. The operational check can be the basis for troubleshooting. Notice all the symptoms of unsatisfactory system operation. Determine the difference between normal operation and unsatisfactory operation. The analysis of the trouble during the operational check can be fairly simple if you know the following:

- Why you perform the check.
- Purpose of each part of the check.
- What units you check.
- What is taking place within the system during the check.

Investigate and research. The next step is to enforce your knowledge of system details. The −2 technical manual for your aircraft provides information on the purpose and construction of each unit in the system. The TO also contains a schematic or diagram that shows how the lines and units of the system are connected. Troubleshooting charts are usually included in the −2 TO.

Troubleshooting charts are similar in design. However, they vary in the way in which they cover the various systems. They state the trouble, probable cause, isolation procedures, and corrective action. When such a chart is available, use it. Normally, the chart has the common troubles listed in the left-hand column. Look through the troubles until you find one that matches the observed trouble indications. See figure 6-18.

Eliminate possibilities. When a troubleshooting chart is available, your elimination of the probable cause of a problem is a simple matter. However, in some cases a chart may not be included in the aircraft manual. Under these conditions, prepare a list of all units in the system that could produce the observed symptoms. After listing all probable causes, examine each unit to determine whether or not it could really cause the trouble. Eliminate those components that could (not) produce all the indicated symptoms.

Isolate trouble. After all of the probable causes have been established, whether through a troubleshooting chart or your own list, analyze the remaining causes from the standpoint of probability. To save time, examine the probable causes that can be checked easily before you try those that require involved check procedures.

Prove your conclusions. Probably the greatest temptation for any troubleshooter is to jump to conclusions. Evidence of this is seen in the number of units removed as "unserviceable" and later shown by bench check to be serviceable. Each of these replacement errors represents a great deal of wasted work and expense. So before reaching a conclusion, use enough checks to prove that you are right.

Correct trouble. To eliminate the trouble, you should correct the fault by repair, replacement, or adjustment of the responsible unit or units. Then operate the system to be sure that you have restored normal system operation.

The first problem you may encounter is that the boom operator's sighting door does not open. One of the probable causes is insufficient pressure in the system. Since the door is actuated by hydraulic pressure, you should check the hydraulic system for proper pressure. By similar reasoning, the "boom operator's sighting door control valve improperly adjusted" is also a likely cause, since the control valve directs the hydraulic pressure to the door actuator. A third cause might be the mechanical lock in the actuator. This lock could be faulty, causing the door to be locked closed. Let's look now at some of the problems you might find in the boom hoist system. Let's say that the boom fails to hoist when the hoist control lever is used. Since the pressure for the boom hoist comes through the sighting door control valve, make sure that the sighting door control valve is in the proper position. If the hoist control valve or linkage is improperly rigged, this, too, could cause this problem. If the boom fails to hoist using the hoist hand pump, the cause could be that the manual shutoff valve is improperly positioned, or the hand pump is defective. If the boom fails to extend or retract, the boom telescoping control linkage may be improperly adjusted. A defective telescoping control valve could also be guilty. If the boom extends or retracts sluggishly, check the accumulator for specified air pressure. Problems encountered in the ruddevator system primarily consist of leakage and rigging. Since the auto retract fuel bypass and the fuel dump systems consist of electro-hydraulic valves, most of your malfunctions, other than leakage, would be from the control valves not energizing.

Now let's look at some of the problems you may encounter in the A/R electrical system. What if the READY indicator light does not illuminate when the master switch is ON? Looking at foldout 11, you see that a faulty signal amplifier circuit breaker is a probable cause, since it connects power to the circuit. By a similar line of reasoning, a defective A/R master switch will disconnect power from the circuit also. Defective wiring, signal amplifier, or possibly the light bulb burned out could also

TROUBLE	PROBABLE CAUSE	ISOLATION PROCEDURE	REMEDY
Boom extends or retracts sluggishly	No preload on accumulator	Check accumulator for specified pressure	Recharge accumulator
	Defective telescope control valve	Open sighting door and check response of boom by manually moving valve arm	Replace defective control valve [1]
Ruddevator power unit leaking at exposed piston rod seal, at opening near head end mounting bolt, at exposed slide seal or at drain hole in slide plug	Defective piston rod seal or slide seal	Wipe area dry. Pressurize right hydraulic system. Position door control lever to OPEN. Move ruddevator control stick through five full cycles in either azimuth or elevation direction. Depressurize system and check for leakage	If leakage at any one point exceeds one drop, replace power unit [1]

[1] After replacement of system components or associated tubing, bleed the hydraulic system per applicable component installation paragraph.

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Figure 6–18. Troubleshooting.

cause this malfunction. Now what could be the problem if the signal system fails to advance to MADE condition upon contact with the aircraft? Since the signal coil sends the MADE signal to the amplifier, the cause could be that either the signal coil or the amplifier has malfunctioned. The signal coil has been known to corrode and cause this problem. If the MADE light fails to come on, the cause could be a defective bulb or wiring. The same is true of the DISCONNECT light. If the signal system fails to go to disconnect after reaching the envelope limits, the elevation, telescope, or azimuth limit switches are at fault. The items that can malfunction in the fuel dump system, other than the hydraulic components, are the fuel dump switch, fuel dump relay, and the fuel dump limit switch. As you can see by looking as foldout 11, if any of these items were defective it could prevent the dumping of the fuel overboard.

Exercises (666):

1. As you try to open the boom operator's sighting door, hydraulic pressure is available. However, you find the door remains closed. What is the probable cause of this failure?

2. During a refueling mission, the boom operator reports to the pilot that the boom cannot be raised normally. What is the probable cause of the malfunction?

3. Using the hand pump to raise the boom in an emergency, it is found that pressure would not build up. There is enough fluid in the system, plus the filter is not clogged. What could possibly cause this malfunction?

4. During an operational check of the A/R system, you find that the READY indicator light does not illuminate when the A/R master switch is in the ON position. What should you check first?

5. You are dispatched to troubleshoot the A/R system on an aircraft that has just returned from a mission. No contact (MADE) signal was received when the boom made contact with the receiver aircraft. What is the most likely trouble and how should you correct it?

6. During an operational check of the boom hydraulic system, you observe that the boom is retracting very slowly. At the same time, you observe that the boom hydraulic pressure is fluctuating. What could be the problem, and how should you correct this situation?

6-4. Bench Check and Repair of Inflight Refueling System Components

Since many of the hydraulic components, such as selector valves and actuators, have already been discussed in other chapters of this course, this section will discuss components strictly used in the inflight refueling system. Two items that we feel are representative of the inflight refueling system are the boom nozzle and the signal amplifier.

667. State procedures to follow during bench check and repair of a fuel nozzle used on the inflight refueling system.

Bench Check and Repair of Boom Nozzle. The nozzle assembly forms the fueltight coupling between the receiver aircraft and the tanker aircraft. Simply speaking, the nozzle (fig. 6-19) is the male half of the quick disconnect, with the female half being in the receiver aircraft. With these thoughts in mind, let's go through the bench and repair of a nozzle assembly.

Various special tools and test equipment are necessary during the disassembly, inspection, reassembly, and testing of this unit. For specific data on the tools and test equipment required, consult the applicable technical order.

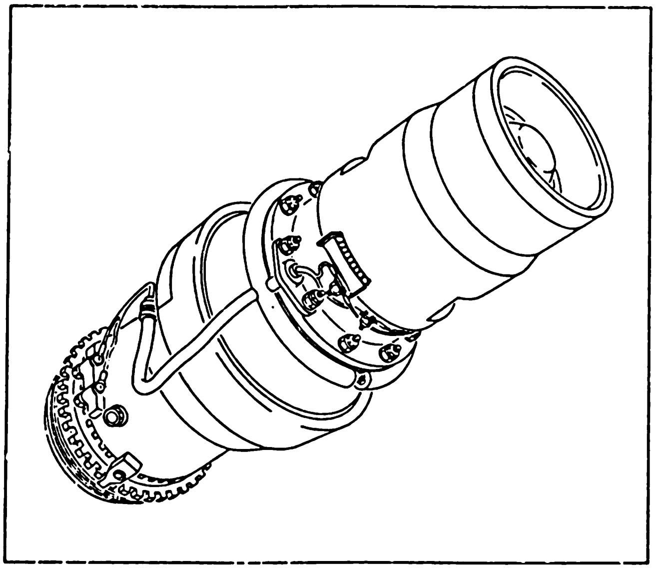

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Figure 6–19. Fuel nozzle.

Disassemble according to numerical sequence of index numbers assigned to exploded view in figure 6-20. Be extremely careful to prevent damage to threads of the nozzle. Clean all parts with PD–680 cleaning solvent, paying particular attention to insure that all grease passages are clean and free of residue. (CAUTION: Solvents may be extremely dangerous; so cleaning operations should always be conducted under well-ventilated conditions, especially when spray or atomized solvents are used.) Where physical contact with the solvent is necessary, use gloves and face shield. After disassembly and cleaning, you should inspect the items, preferably with a strong light and magnification. Inspect all parts for cracks, damage, scoring, excessive wear of machine surfaces, evidence of corrosion, and cross threading. Check alignment of springs by rolling them across a smooth, flat surface. There must be no wobble. Also, give the springs a compression test to insure that they have the proper tension. Check all plated areas to determine if the plated surfaces are worn through. (NOTE: In checking the chrome plated surfaces for a worn-through condition, you may swab the surface with a copper sulphate solution; areas that are worn through will show a visible copper coating.) Replace all parts that are cracked; that show signs of excessive wear, scoring or corrosion; or that are damaged beyond minor repair. Remove mild corrosion, minor nicks, or scores with crocus cloth. Replace sealing ring (65), teflon sliding seal (69), filter (73), and bumper ring (79), as shown in figure 6-20, as well as all O-rings seals. Replace all plated items that show signs of wear, or replace them in accordance with applicable technical orders. During reassembly, lubricate various items with specified lubricants and reassemble them in reverse order of disassembly. During reassembly, be sure to follow the technical order step by step, paying particular attention to all the NOTEs and CAUTIONs. Once the nozzle is reassembled, you are ready to test it. Since the signal coil is an integral part of the nozzle assembly, you should make sure that the polarity of the coils is correct. Remember, the signal coil sends a signal to and from the signal amplifier; so you should make sure that the wiring is connected properly. To check the polarity of the signal coil, connect the blue (+) lead to a 28-volt DC power source and the brown (−) lead to ground (fig. 6-21). Then hold a magnetic directional compass between the two pole pieces of the coil. The north end of the compass needle must point toward wires extending from the coil, if the polarity is correct. If the polarity is incorrect, check resistance through the signal coil. If resistance is within limits but polarity is still reversed, the leads to the coil may have been reversed on installation.

Some of the other tests that should be done after the nozzle assembly has been reassembled are the operation of the nozzle check valve and the proof and external leakage test. To check the nozzle check valve, push the nozzle check valve in slowly then release. It should move freely and return to the closed position without hesitation or evidence of sticking or binding. In order to perform the proof and leakage tests, the nozzle must be installed in a test set-up similar to the one shown in figure 6-22. To perform proof pressure test, apply approximately 415 psig fluid pressure for a minimum of 30 seconds. There should

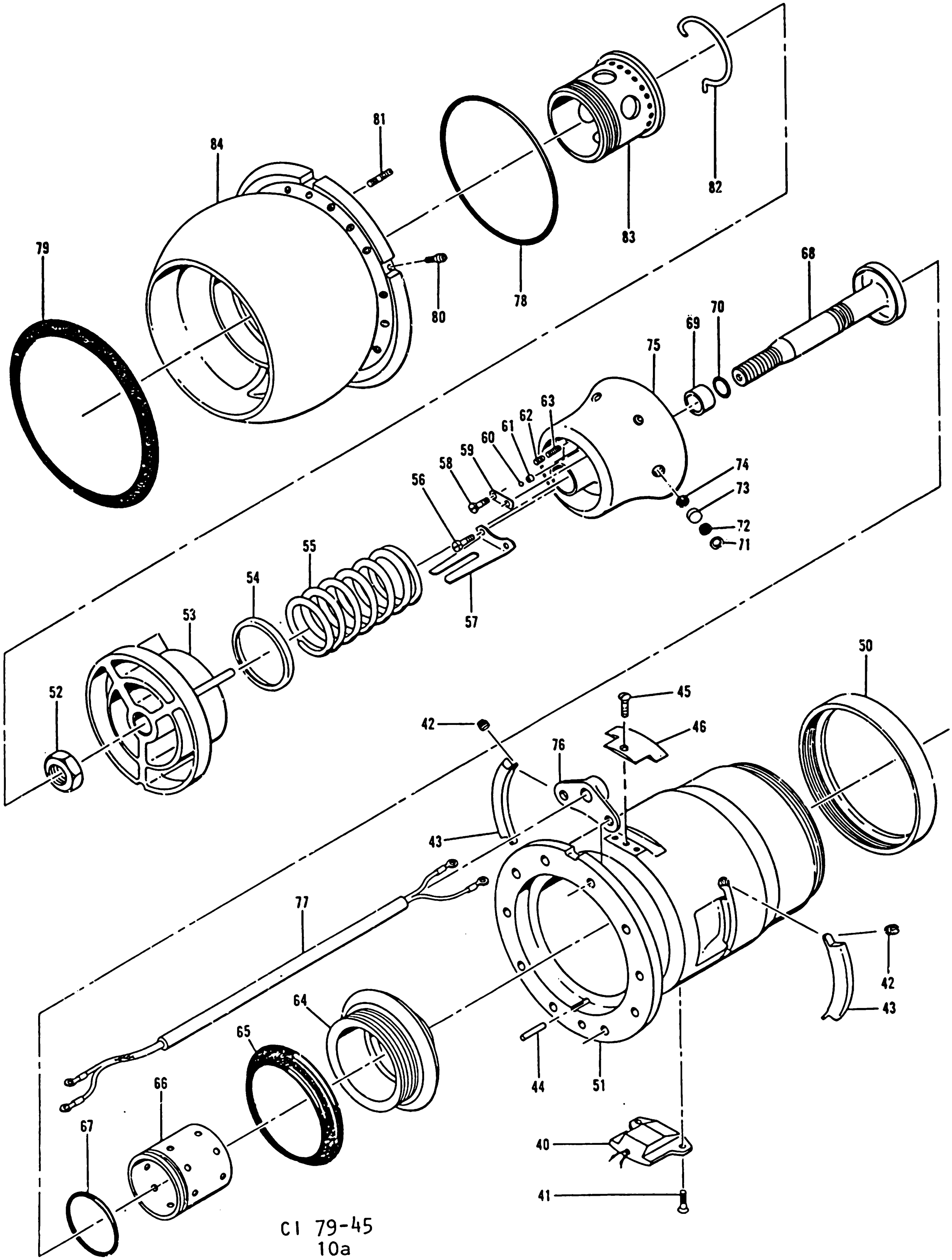

Figure 6–20. Boom nozzle breakdown.

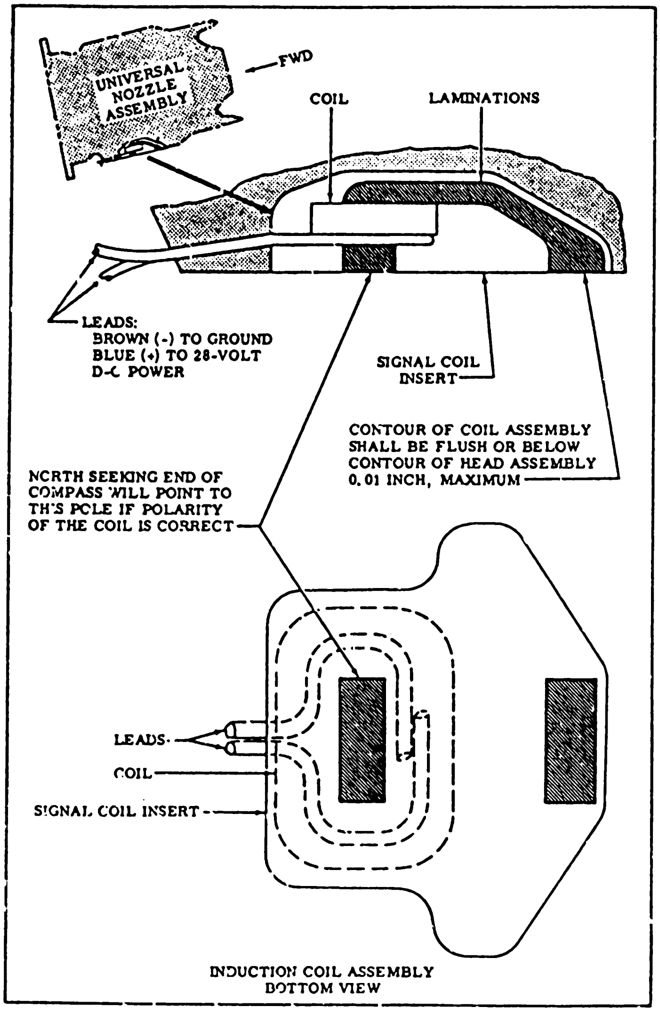

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Figure 6–21. Polarity of signal coil.

be no evidence of failure of any parts. To perform the leakage test, apply 225 psig fluid pressure for a period of 5 minutes. With pressure still applied, rotate the head and check for leakage. Leakage at ball joint and nozzle check valve should not exceed 20 drops per minute. If leakage exceeds allowable drops per minute, replace seals at point of leakage.

Exercises (667):

1. What precaution should be taken when disassembling the nozzle?

2. Give two ways of checking a spring?

3. How can you determine if the chrome plating is worn on specific components of the nozzle assembly?

4. What would be the indication if the wires to the signal coil were reversed during installation?

5. When 415 psig is applied to the nozzle assembly, what is the minimum time it should be applied?

6. What position should the check valve in the nozzle assembly return to when it is released?

668. Specify the procedures to use when testing an inflight refueling amplifier.

Amplifier Testing. The signal amplifier is used to control flying boom inflight refueling operations. The amplifier is actuated by an electrical impulse caused by the momentary application of DC voltage from the airplane system. This voltage pulse fires a gas-filled electron tube, which in turn energizes a series of relays controlling various phases of the refueling operation. To test the amplifier, a special signal amplifier test box, as shown in figure 6-23, must be used. Connect the amplifier to be tested to the test box with the electrical cable which extends from the side of the box. Then connect a 30 volt DC electrical source to the terminals on top of the tester. Be sure to connect the electrical power source to the correct terminals marked negative (−) and positive (+). Now with the electrical power source connected to the test box and the amplifier connected to the test box cable, turn POWER switch to ON position and allow the test box to warm up. Place the voltage switch located on the right side of the test box to the

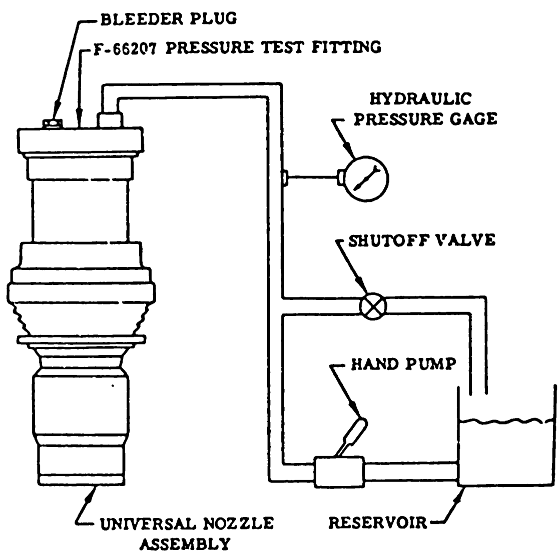

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Figure 6–22. Boom nozzle test set-up.

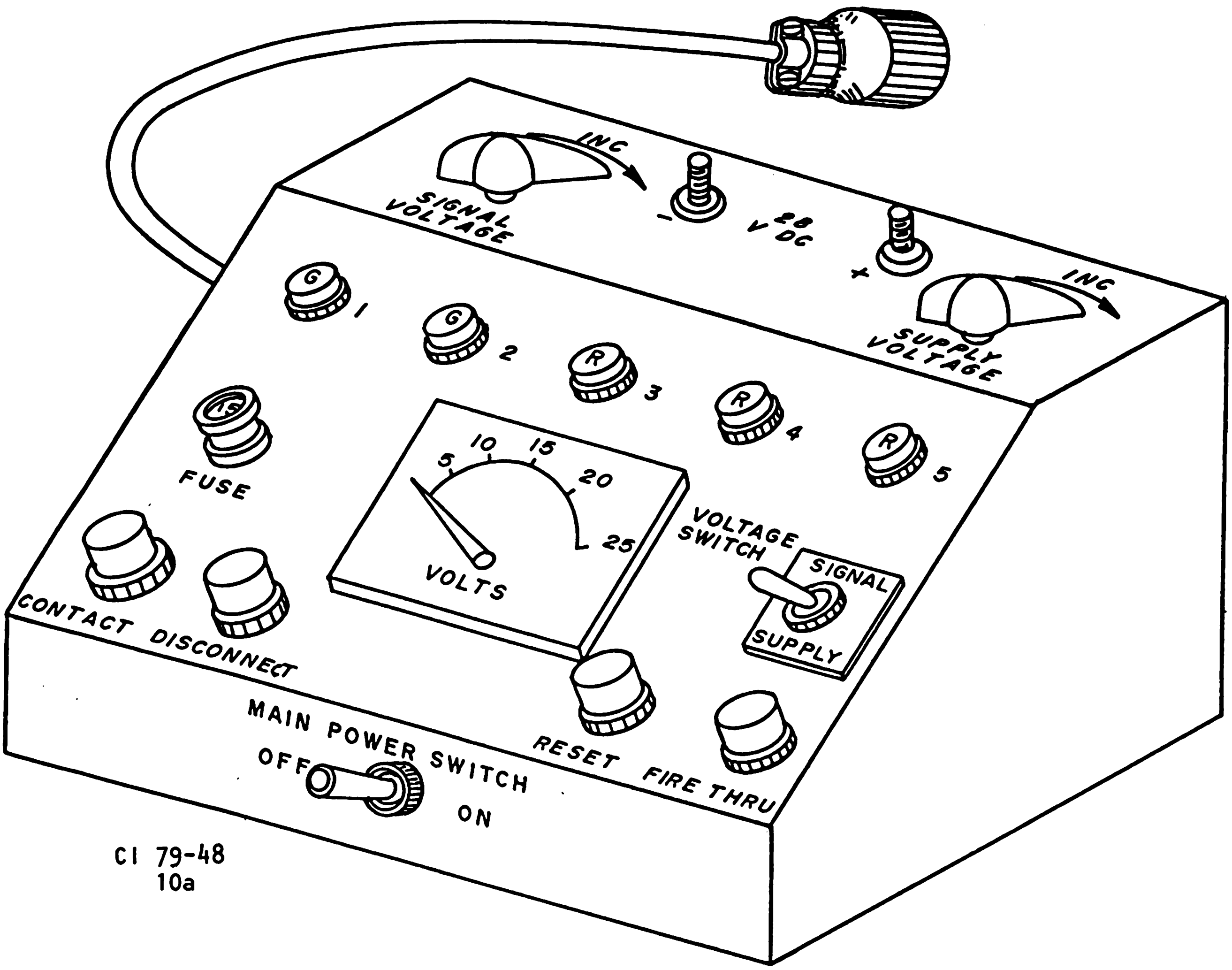


Figure 6–23. Signal amplifier test box.

SUPPLY VOLTAGE position. Then adjust the supply voltage adjust knob on top of the tester so that the voltage meter of the test box reads 30 volts. With the voltage adjusted, the green lights (1 and 2) should be on and the other lights off. Depress the CONTACT switch momentarily; this will cause lights 2, 3, and 4 to come on. Lights 1 and 5 should be off. Depress DISCONNECT switch momentarily. Lights 4 and 5 should be on and the other lights should be off. When the RESET switch is depressed momentarily, lights 1 and 2 should be on, with all other lights off. Now perform a low voltage test. This is done by adjusting the SUPPLY VOLTAGE adjust knob until you read approximately 21 volts on the test box voltmeter. Now, simply repeat the previous steps. Another test that should be done to determine if the amplifier is functioning properly is the sensitivity test. Place the VOLTAGE SWITCH to SUPPLY position and adjust the SUPPLY rheostat so that the panel meter reads 30 volts DC. Throw the VOLTAGE switch to SIGNAL and adjust the SIGNAL rheostat so that the panel meter reads 5 volts DC. Then depress the FIRE THRU switch momentarily. This will cause lights 1 and 2 to remain on with the other lights off. Adjust the SIGNAL voltage rheostat so that the panel meter reads 12 volts DC. Depress the FIRE THRU switch again momentarily, this will cause lights 4 and 5 to come on and the other lights off. Depress RESET switch next, momentarily, lights 1 and 2 should come back on and the other lights should go off.

If the signal amplifier fails to function properly, a relay, tube, or electrical connection in the amplifier has malfunctioned. As an example, when the CONTACT switch is depressed, nothing happens. This would indicate that the electron tube or relay is defective.

Exercises (668):

1. List two tests that should be performed on the inflight refueling amplifier.

2. Which lights should be on when power is first applied to the test box?

3. What precaution should you take when connecting electrical power to the test box?

4. How is the test box connected to the signal amplifier?

5. Which position should the voltage switch be placed in when the voltage meter is reading 12 volts and the FIRE THRU switch is depressed?

Cargo Doors and Ramp and Test Stands

CARGO AIRCRAFT are unique to any other type aircraft in that they can carry a variety of payloads. These payloads can be in the form of passengers, as well as ground equipment, spare parts, and even other aircraft.

In order for the larger objects to be placed on board the aircraft, the aircraft must have a large door system and some type of loading ramp. This chapter will discuss the clamshell-type cargo (petal) doors, auxiliary petal doors, cargo ramp, and a pressure door. Unfortunately, not all the aircraft door systems can be talked about in this course, so we have selected the door system of a common cargo aircraft which is representative of most cargo door systems with a few minor variations.

7-1. Cargo Doors Electrical Operation

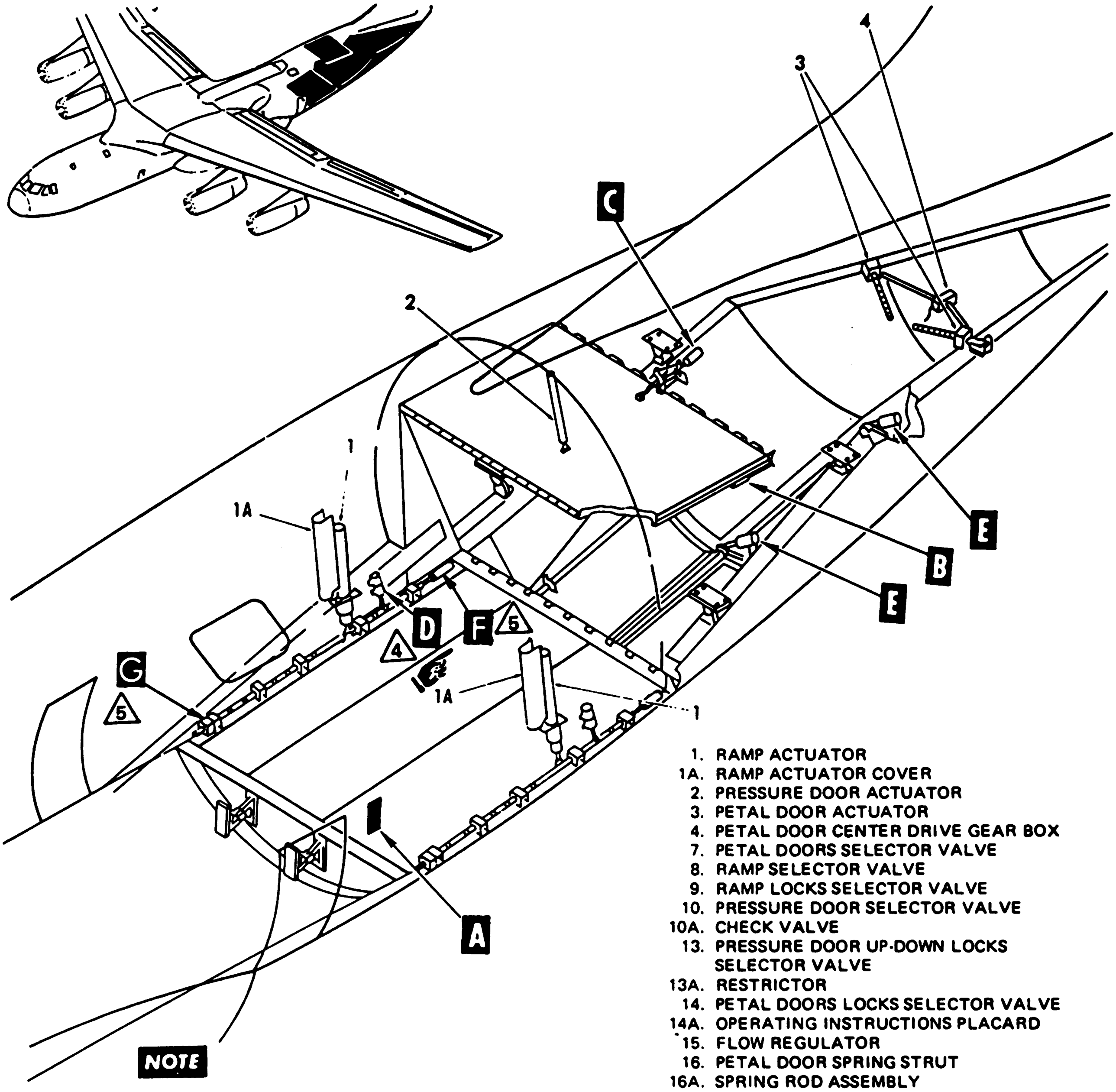
The use of cargo doors makes it possible to load and deploy payloads both while the aircraft is on the ground and also while the aircraft is airborne. Pressure from the aircraft's No. 3 hydraulic system permits the operator to open and close the doors in the normal and the override modes. The doors are hydraulically actuated and locked, and electrically controlled from the paradrop and Automatic Door System (ADS) panels on the pilot's and copilot's consoles. The system can also be operated from the doors and ramp control panel in the cargo compartment. A DOOR ARMING switch is on the pilot's paradrop and ADS panel. An ALL DOORS control switch is on the pilot's and copilot's panels and on the doors and ramp control panel. A PRESSURE DOOR ONLY control switch is on the crew door interphone panel near the crew entrance door. In flight all doors may by controlled from the flight station. Let us begin our discussion with the electrical operation of the pressure door.

669. Specify the procedures for electrical operation of the pressure door.

Pressure Door Operation. The pressure door seals off the cargo compartment from the unpressurized empennage. This door is a hinged honeycomb structure raised up and aft to the top of the cargo compartment by a single hydraulic actuator. The pressure door system is provided with a single uplock actuator (fig. 7-3C, item 21), a pressure door actuator (fig. 7-1, item 2), two downlock actuators (fig. 7-2B, item 19), a lock selector valve (fig. 7-2A, item 13), and a door actuator selector valve (fig. 7-2A, item 10). When the pressure door is selected to the UP, or OPEN position (fig. 7-4), hydraulic pressure is first ported to the close side of the pressure actuator. This allows the locking hooks to mechanically unlock from the ramp fittings before the selector valve of the pressure door actuator is energized. Once energized the retract side and the door opens aft and up. In the UP position the door is mechanically locked by a lock actuator. At this time, the door closes a switch which causes pressure on the pressure door actuator to be relieved through the deenergized selector valve. The selector valve is then in the "block center" position. In this position all ports are blocked at the control valve, and fluid is trapped in both lines to the actuator. As the uplock engages, limit switches are actuated to complete petal door and ramp control circuits.

Door Arming. To open the pressure door in the air (fig. 7-5) the DOOR ARMING switch must be in the ARM position. This will allow power to be supplied to one of the pressure door switches. Placing the PRESSURE DOOR switch to the OPEN position supplies power to the pressure door selector valve unlock solenoid. At the same time, power is supplied to the pressure door actuator selector valve close side. This applies hydraulic fluid under pressure to the close side of the door actuator, and allows the uplock solenoid to release the locks fastening the pressure door to the ramp fittings. As the hooks rotate to the unlock position, a pressure door downlock limit switch removes power from the close side of the selector valve. This applies hydraulic fluid to the rod side of the actuating piston, and the piston is retracted. This action causes the door to be opened aft and up. When the door is in the full UP position, it engages a latch which is part of the pressure door uplock mechanism.

Closing the Door While in the Air. To close the pressure door while in the air (fig. 7-6), the DOOR ARMING switch must be in the ARM position. This position supplies power to the pressure door through the touchdown relay and pilot's and copilot's ALL DOORS switches, when in the OFF position. Placing either pressure door switch to the CLOSE position will supply power to the open side of the pressure door actuator selector valve and to the unlock side of the pressure door lock selector valve. This preloads the door in the OPEN position and at the same time applies pressure to the uplock actuator. When the uplock actuator releases, the pressure door uplock limit switch is actuated. Power is then supplied to the close side of the pressure door actuator and the door is closed. When the door is completely closed, the pressure door down limit switches are actuated. This action supplies power to the



1. RAMP ACTUATOR
1A. RAMP ACTUATOR COVER
2. PRESSURE DOOR ACTUATOR
3. PETAL DOOR ACTUATOR
4. PETAL DOOR CENTER DRIVE GEAR BOX
7. PETAL DOORS SELECTOR VALVE
8. RAMP SELECTOR VALVE
9. RAMP LOCKS SELECTOR VALVE
10. PRESSURE DOOR SELECTOR VALVE
10A. CHECK VALVE
13. PRESSURE DOOR UP-DOWN LOCKS SELECTOR VALVE
13A. RESTRICTOR
14. PETAL DOORS LOCKS SELECTOR VALVE
14A. OPERATING INSTRUCTIONS PLACARD
15. FLOW REGULATOR
16. PETAL DOOR SPRING STRUT
16A. SPRING ROD ASSEMBLY
17. PETAL DOOR LATCH HOOK
18. PETAL DOOR LOCK ACTUATOR
19. PRESSURE DOOR DOWNLOCK ACTUATOR
20. PRESSURE DOOR UPLOCK HOOK
21. PRESSURE DOOR UPLOCK ACTUATOR
21A. PRESSURE DOOR UPLOCK INDICATOR
22. RAMP LOCK TORQUE TUBE
22A. CARGO RAMP LATCH CATCH MECHANISM
22B. RAMP POSITIVE LOCK/INDICATOR
23. RAMP LOCK ACTUATOR
24. RAMP LOCK ACTUATOR
25. MANUAL SAFETY PIN
26. RAMP LOCK PIN
27. RAMP ECCENTRIC CYLINDERS
28. RAMP LOCK CONNECTING ROD

NOTE

1. AIRCRAFT AF61-2775 THROUGH 61-2779, AF63-8075 THROUGH 63-8080.
2. AIRCRAFT AF63-8081 AND UP.
3. AIRCRAFT MODIFIED PER T.O. 1C-141A-1464.
4. AIRCRAFT NOT MODIFIED PER T.O. 1C-141-513.
5. AIRCRAFT MODIFIED PER T.O. 1C-141-513.

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Figure 7–1. Cargo doors and ramp.

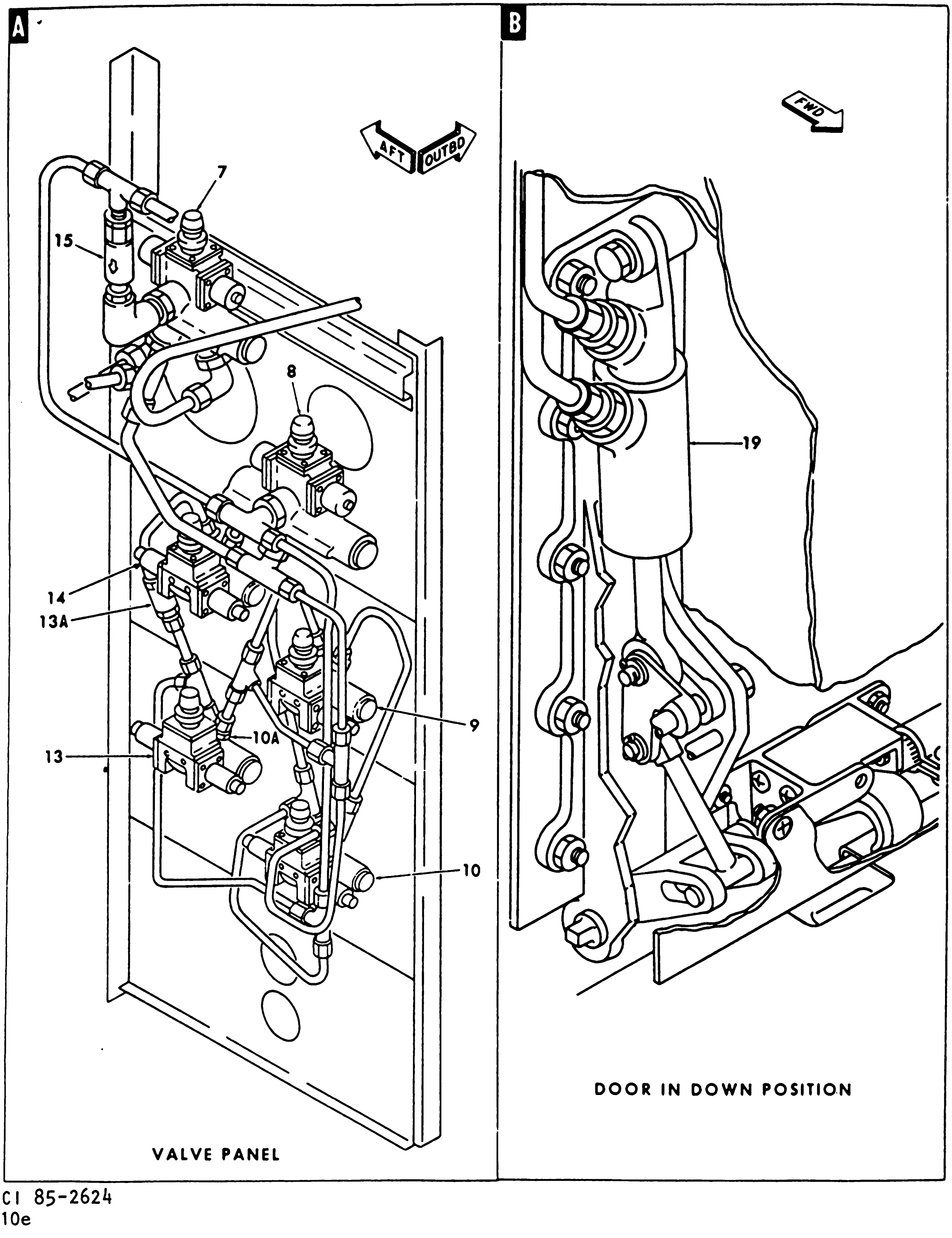

Figure 7–2. Cargo door selector valve side panel.

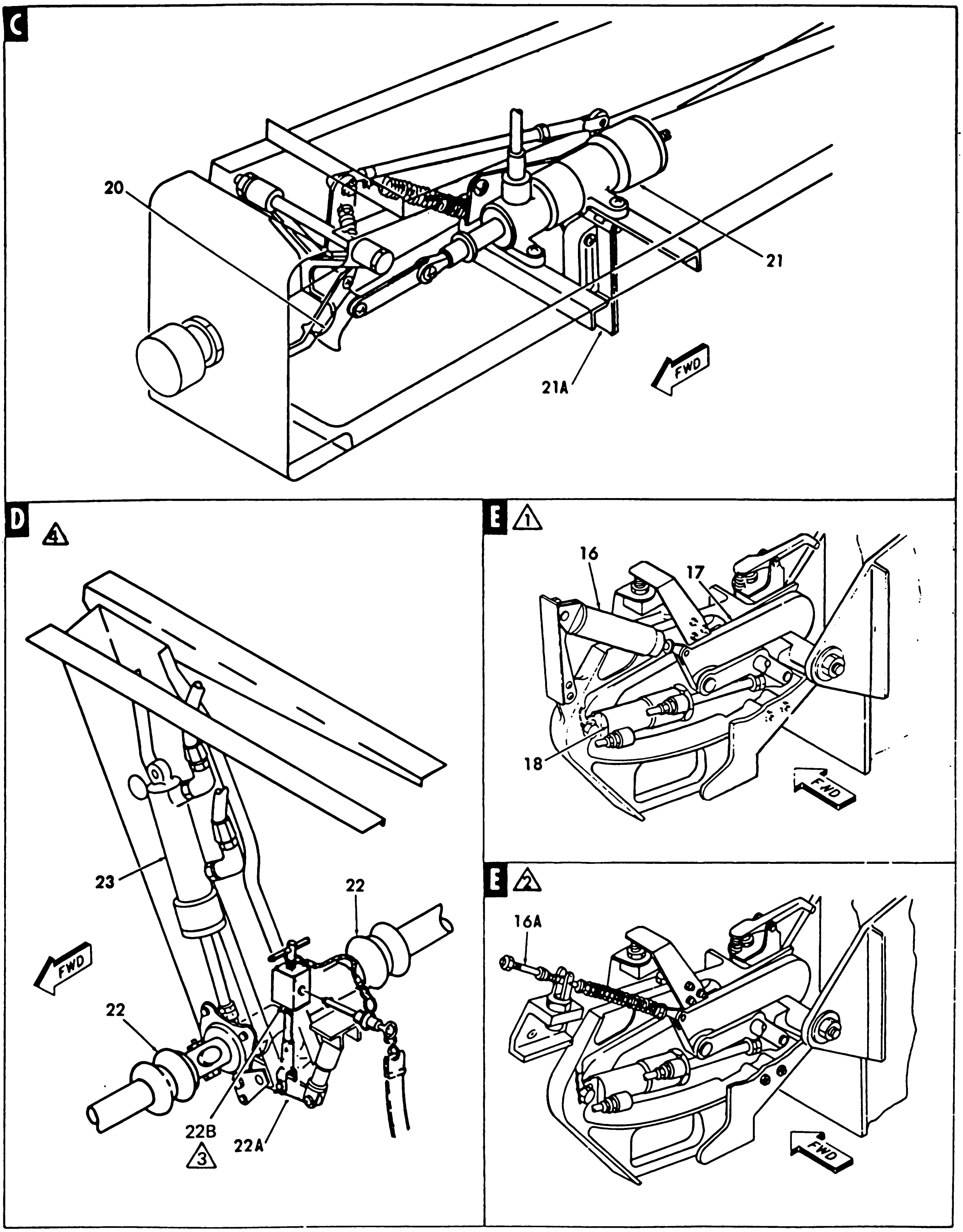

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Figure 7–3. Actuator location.

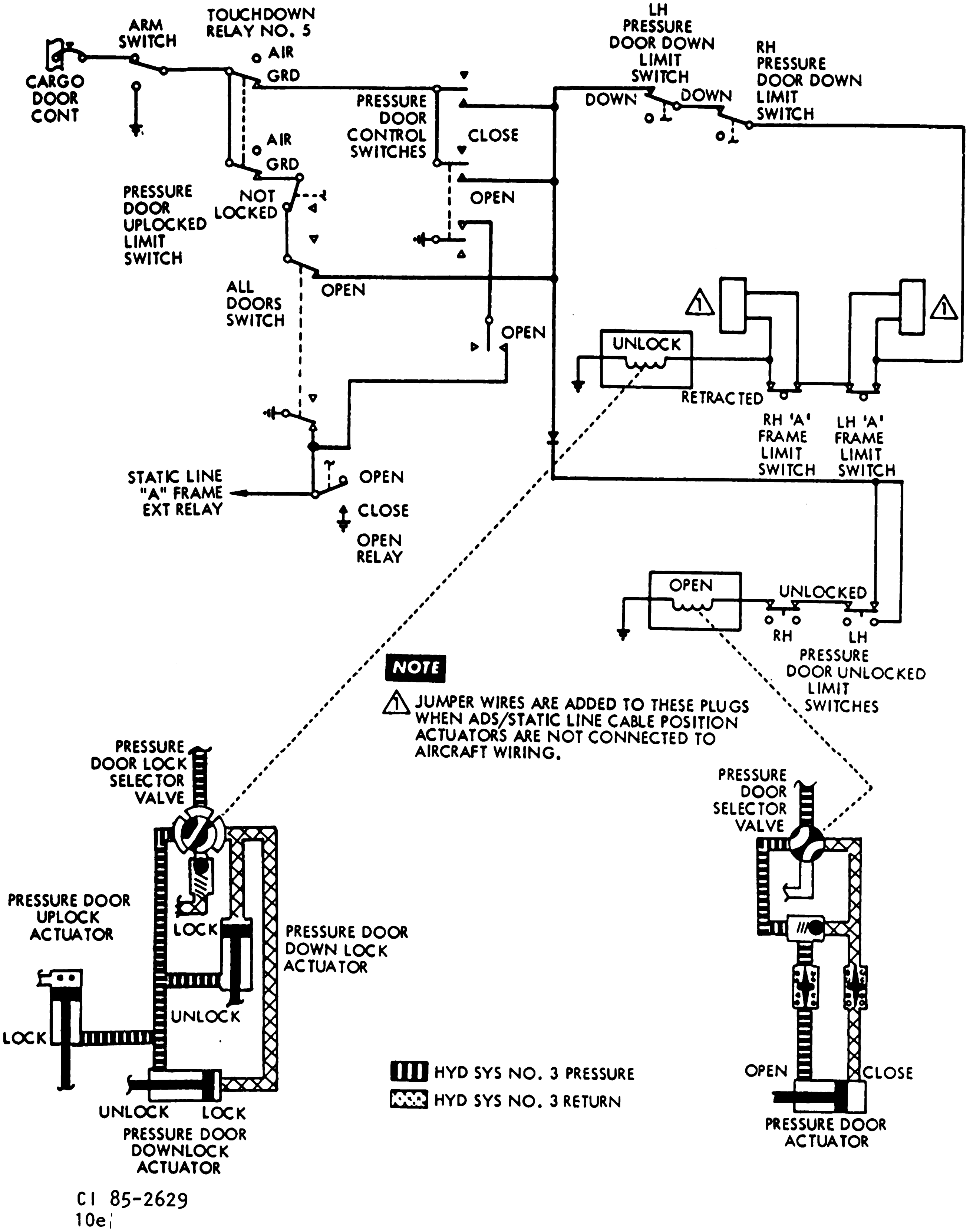


Figure 7–4. Pressure door ground operation (open).

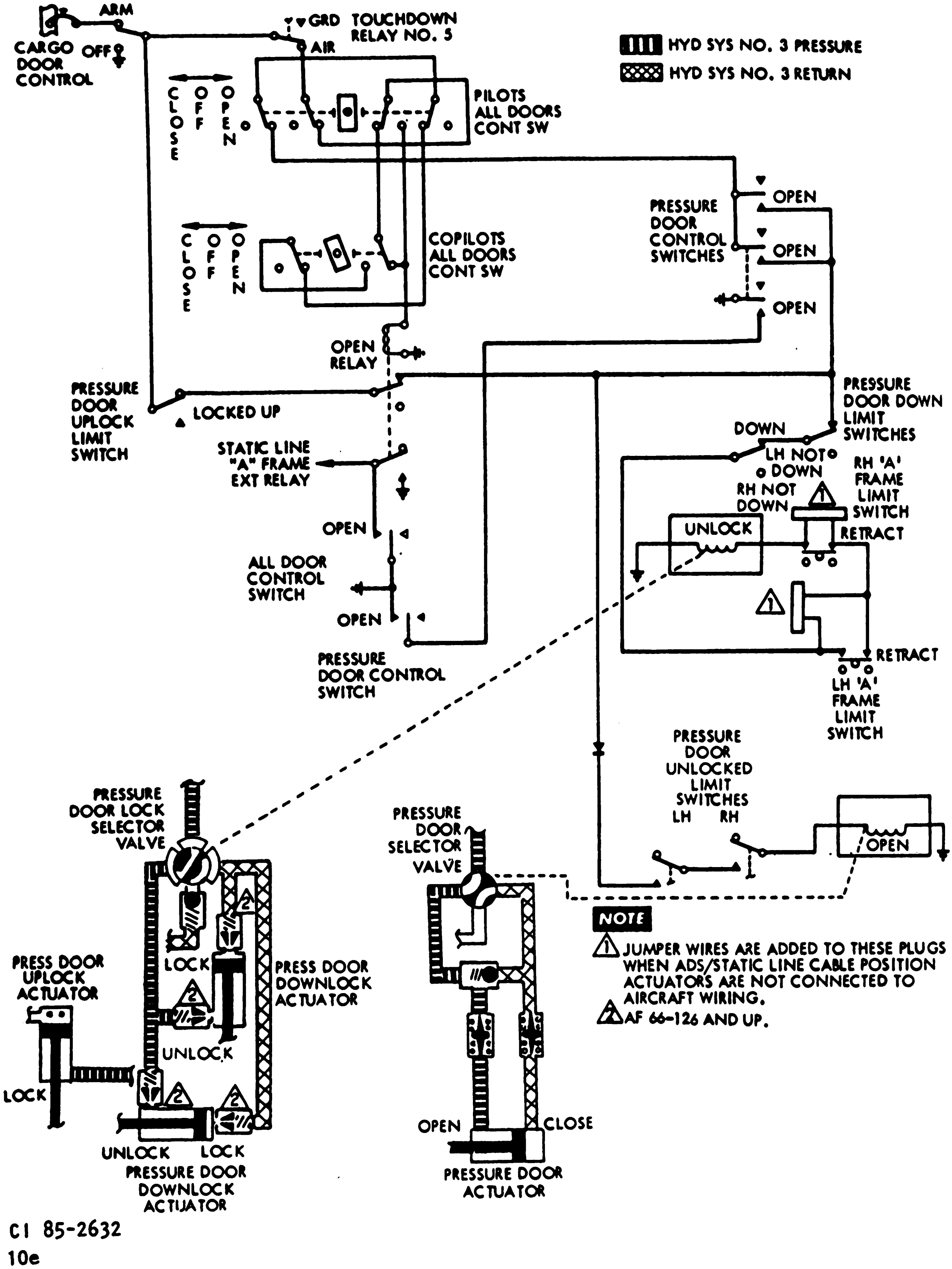


Figure 7–5. Pressure door air operation (open).

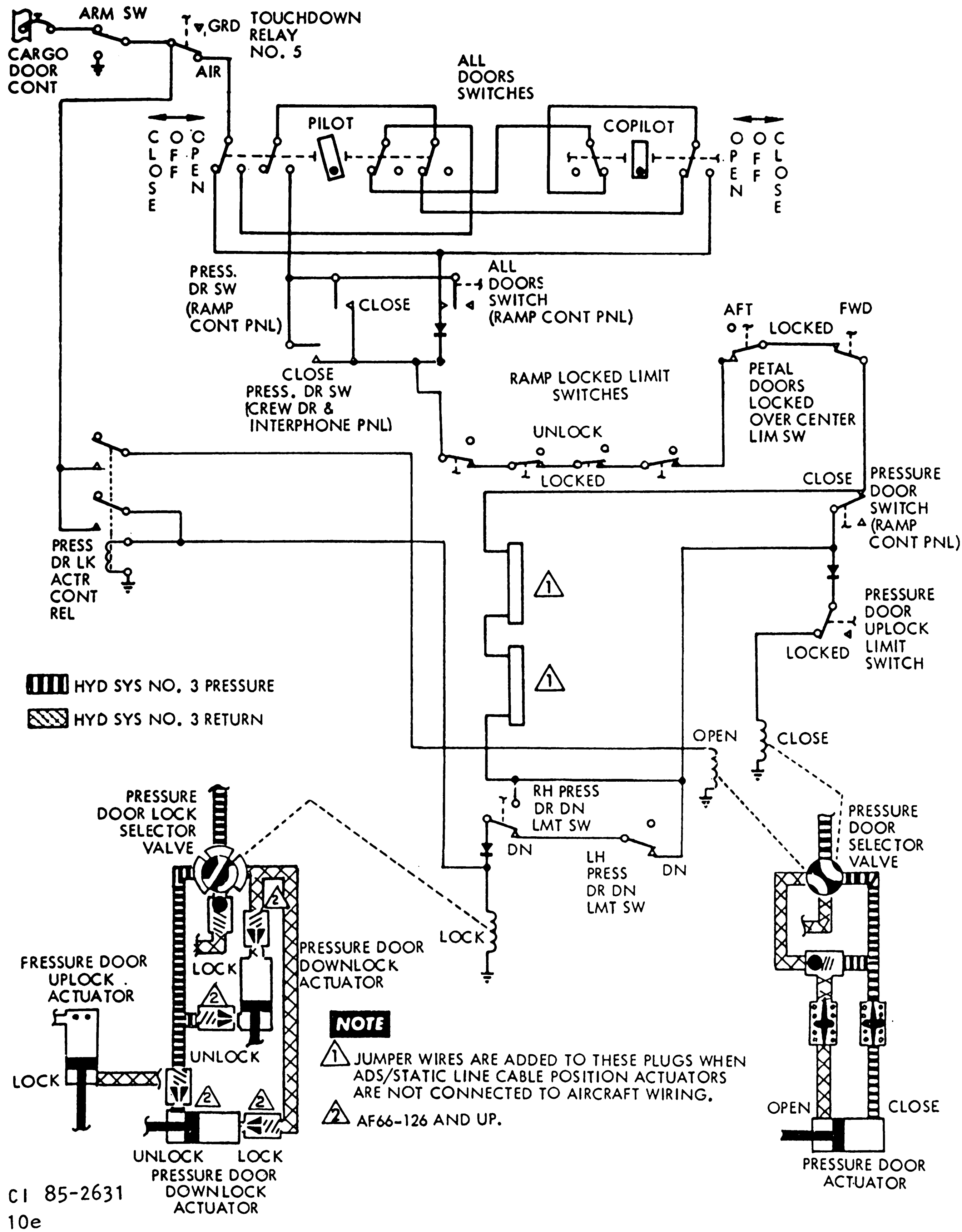


Figure 7–6. Pressure door air operation (close).

lock side of the pressure door lock selector valve. The door locks will then rotate to lock the door.

Pressure Door Opening While on the Ground. If the aircraft is on the ground with all doors closed and the pressure door is to be opened, place the DOOR ARMING switch to ARM to supply power to the touchdown relay and to both pressure door switches. Then place the PRESSURE DOOR switch to OPEN to energize the selector valves and open the door. If the door is open and the PRESSURE DOOR switch is in the CLOSE position, power is supplied to the pressure door unlocked limit switches. The door is preloaded to the OPEN position until the pressure door uplock actuator releases the door and the valves are electrically sequenced to the CLOSED position. After closing, the downlock limit switches actuate to supply electrical power to the door lock selector valves; hydraulic pressure is routed to the lock actuators to lock the door in the CLOSED position.

Exercises (669):

1. What is the purpose of the door actuator selector valve?

2. To close the pressure door while in the air, the DOOR ARMING switch must be in what position?

3. If the aircraft is on the ground with all doors closed and the pressure door is to be opened, in what position is the DOOR ARMING switch placed?

4. When operating the pressure door, why is it necessary for the fluid pressure to be ported to the close side of the actuator first?

5. When is it not possible to operate the pressure door from the flight station?

670. Specify the procedures for electrical operation of the petal doors.

Petal Door Operation. If the petal doors are to be opened or closed, the ALL DOORS switch will be placed in the OPEN position. The pressure door will open first and then the ramp and petal arrangement (fig. 7-1, item 4) to open or close the petal doors. The petal doors are locked after the doors are closed. To open the petal doors in the air (fig. 7-7), the DOOR ARMING switch is placed in the ARM position. This supplies power to the pilot's and copilot's ALL DOORS switches. Placing either the pilot's or copilot's switch (fig. 7–8) in the OPEN position energizes the open relay. Power is then allowed to go through the close relay, which is deenergized, through the door select relay to the open side of the door actuator selector valve. The ground for the open solenoid is supplied through the petal door at the 65° (or 38°) limit switch, through the petal-doors-unlocked limit switches to ground. At the same time power is supplied to the open solenoid of the actuator selector valve, it is also applied through the closed contacts of the door select valve relay to the unlock solenoid of the petal door lock selector valve and to ground. As soon as the doors are unlocked, the petal-doors-unlocked limit switches are closed and a ground is furnished to the open solenoid of the petal door actuator, and the doors open to 65°. A limit switch then opens the ground path, and the open solenoid is deenergized. If the doors should move toward the CLOSED position, closing the LIMIT switch, the doors are immediately pressurized back to the open-at-38° position.

Petal Door Closing in Flight. To close the petal doors in flight (fig. 7-9), the DOOR ARMING switch must be in the ARM position. This supplies power to the pilot's and copilot's ALL DOORS switches which, when placed in the CLOSE position, will energize the close relay. Then power is supplied through the number five touchdown relay, through the pressure door uplocked limit switch, through the deenergized contacts of the close relay, to the close solenoid of the petal door actuator selector valve. Ground for the solenoid is supplied through the petal doors closed limit switches. As soon as the petal doors are in the fully CLOSED position, these LIMIT switches are actuated to open the ground circuit to the close solenoid of the actuator selector valve. The actuator locks are then locked. The other side of the petal door closed limit switches open, and power is removed from the lock selector valve.

Petal Door Opening on the Ground. To open the petal doors on the ground, (fig. 7-10) the DOOR ARMING switch must be in the ARM position. This action supplies power to the ALL DOORS switches. The pressure door must be in the OPEN position to actuate a pressure door uplocked limit switch. Power is then applied through the ALL DOORS switch OPEN position contacts, through the door select relay, to the unlock solenoid of the petal door lock selector valve. The door then unlocks, closing the door unlocked limit switches. When power was supplied to the unlock selector valve, power was also supplied to the petal door actuator selector valve open solenoid. A ground path is supplied through the petal doors unlocked limit switches, the petal-door-55/80° selector switch, the No. 55 touchdown relay, and the 80° limit switch to the open solenoid. The doors now open. If the doors move toward close, the 80° switch again provides a ground and the doors are pressurized back to open.

Petal Door Closing on the Ground. To close the petal doors on the ground (fig. 7-11), the ALL DOORS switch is placed to the CLOSE position. Power is supplied through the DOOR ARMING switch and the ALL DOORS switch to energize the close relay. Then power can pass through the pressure door uplocked limit switch, the close relay, and the close solenoid of the petal door actuator selector valve.

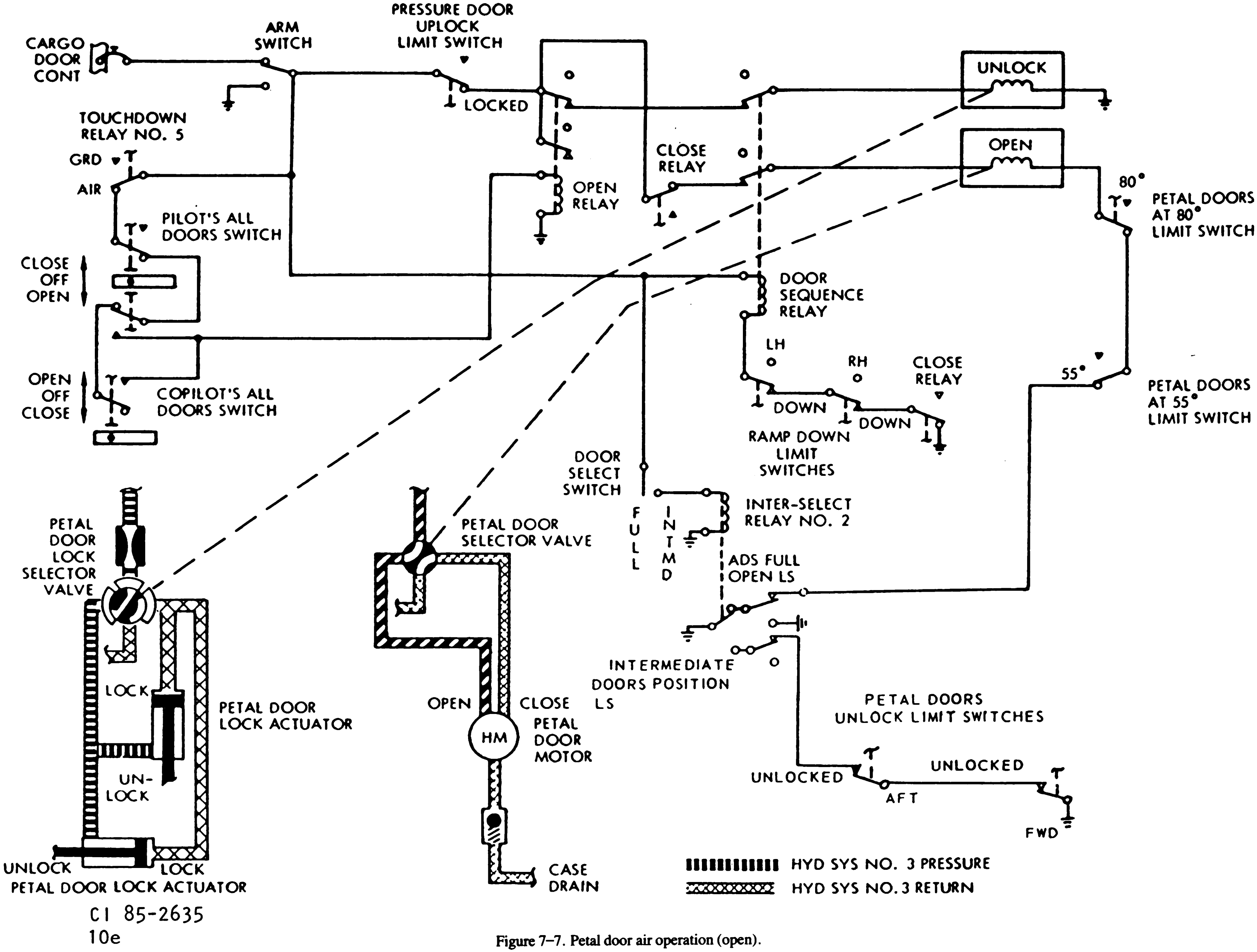
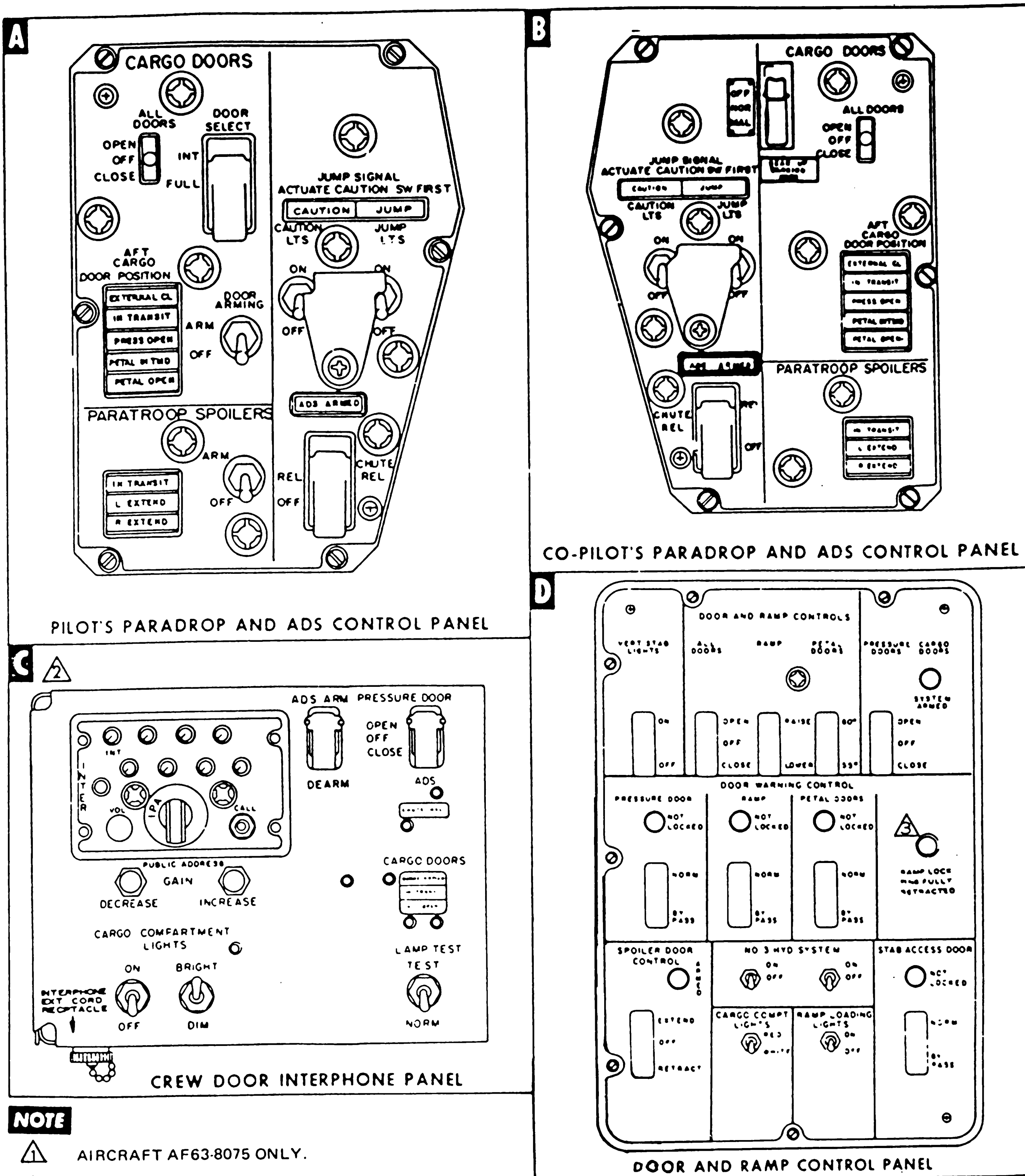


Figure 7–7. Petal door air operation (open).



NOTE

1. AIRCRAFT AF63-8075 ONLY.
2. AIRCRAFT AF61-2775 THROUGH 61-2779, AF63-8076 AND UP.
3. ON AIRCRAFT MODIFIED PER T.O. 1C-141-513.

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Figure 7–8. Cargo doors and ramp control panels.

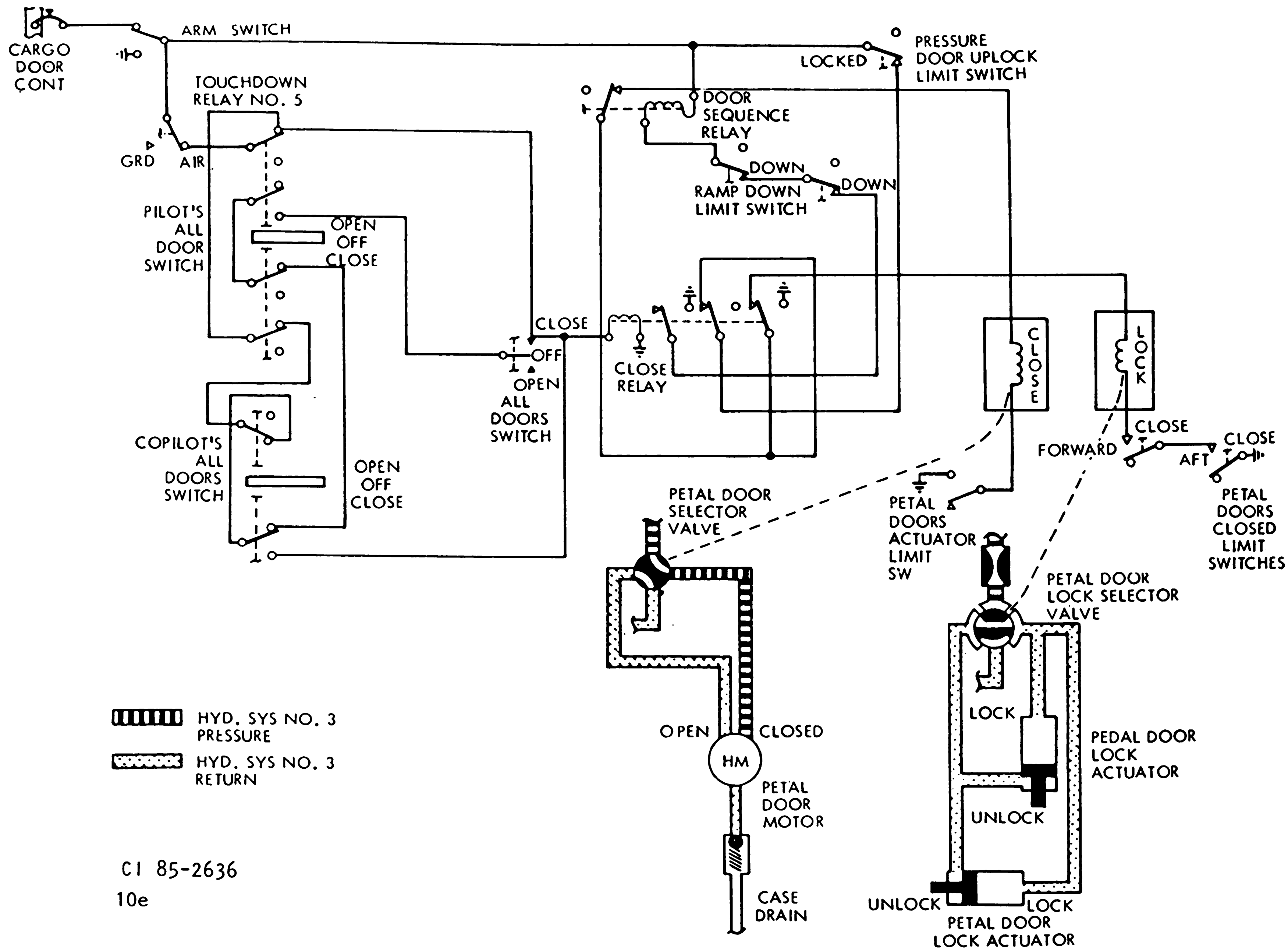


Figure 7–9. Petal door air operation (close).

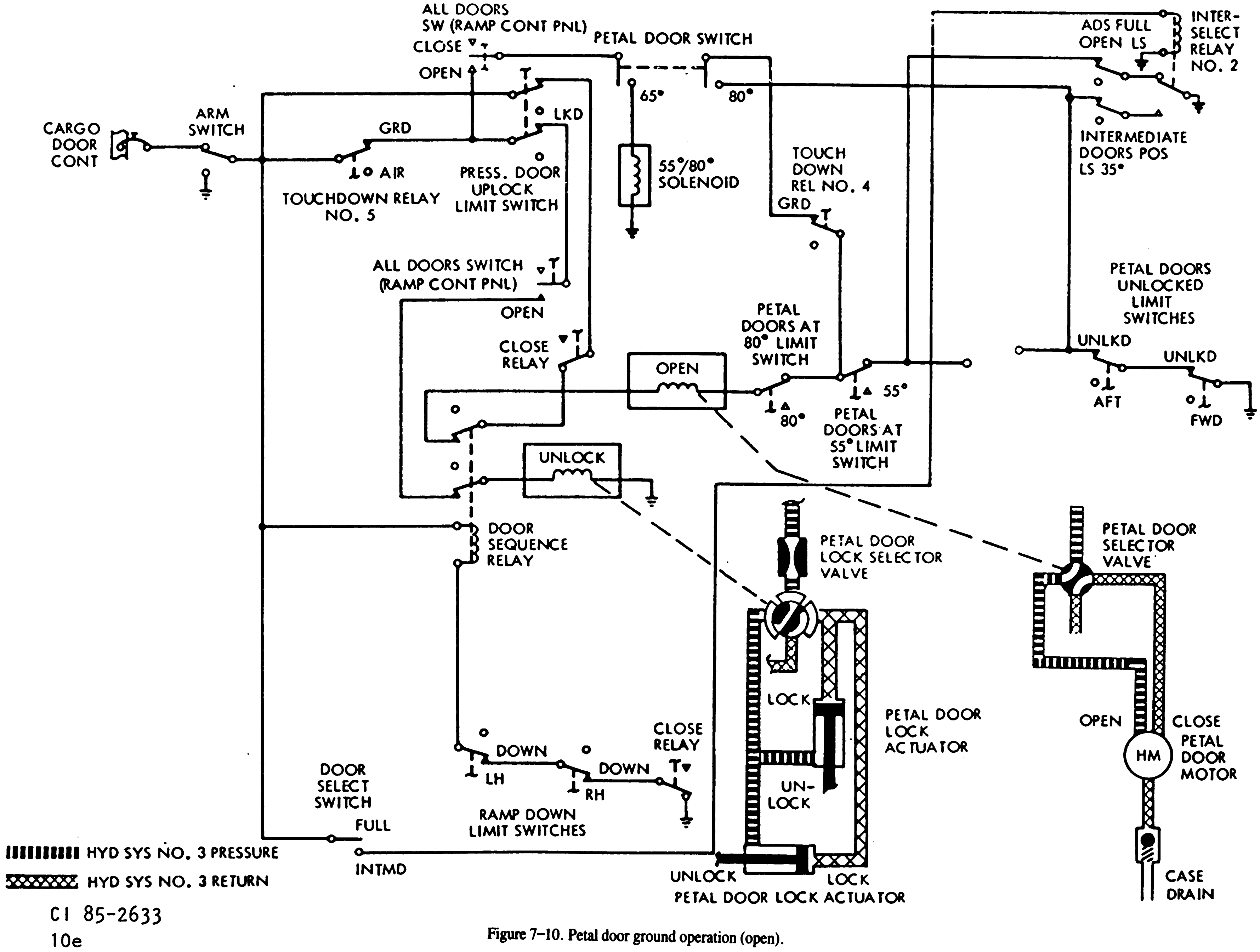


Figure 7–10. Petal door ground operation (open).

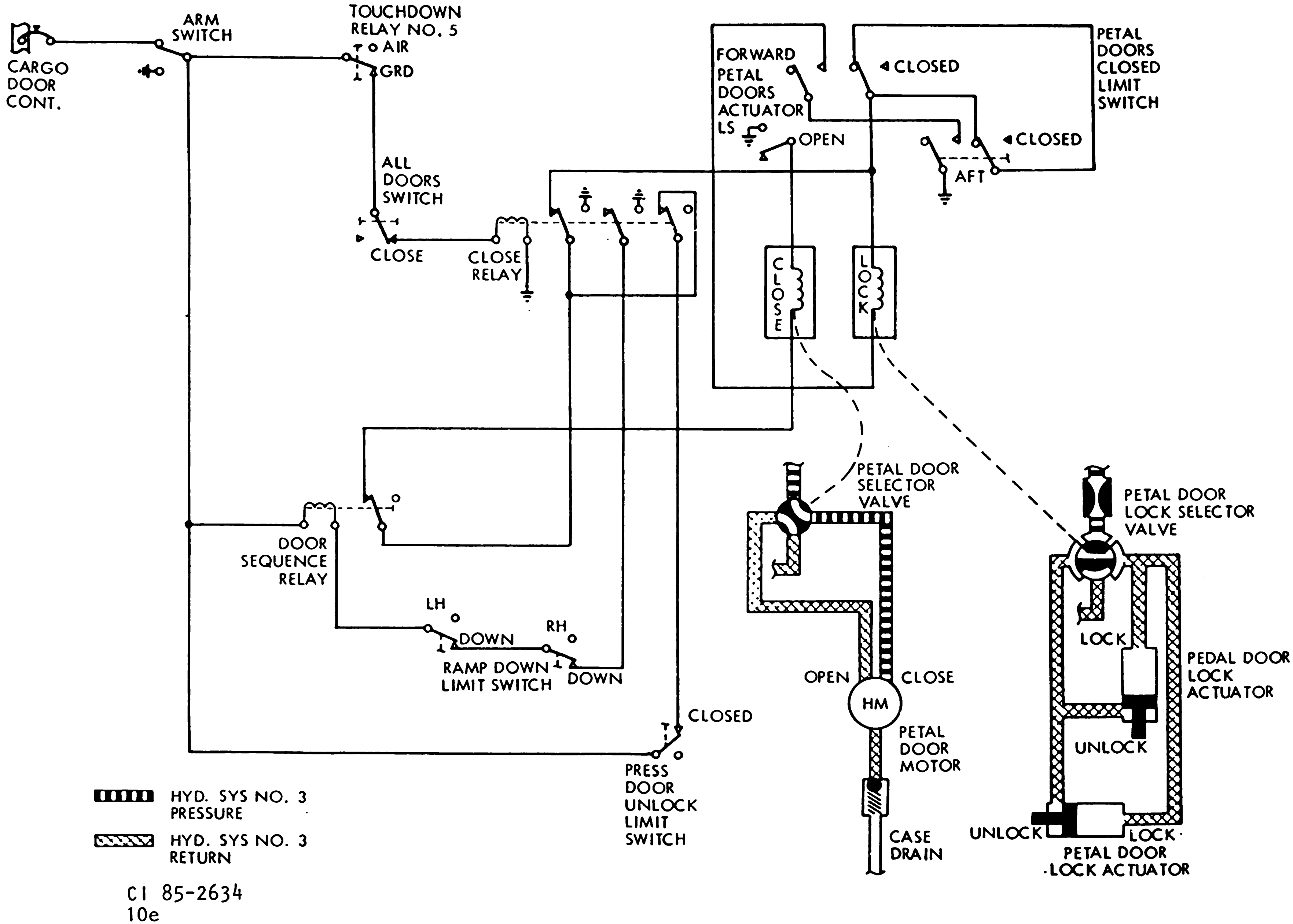


Figure 7–11. Petal door ground operation (close).

A ground path is furnished through the petal doors closed limit switches. When the petal doors are completely closed, the petal door closed limit switches are actuated and a ground path is furnished to the lock solenoid of the petal door lock selector valve. Hydraulic pressure is then ported to the lock side of the locking actuators and the doors are locked.

Exercises (670):

1. If the petal doors are to be opened or closed, the ALL DOORS switch must be placed in what position?

2. Placing either the pilot's or copilot's switch to the OPEN position energizes what relay?

3. What is the maximum limit that the petal doors can be opened?

4. What prevents the petal doors from closing when the doors move toward the CLOSED position?

5. What type of mechanical arrangement is used to operate the petal doors?

671. Specify the procedures for operation of the ramp door system.

Cargo Ramp Operation. The cargo ramp is actuated by two hydraulic cylinders extending from the aircraft structure to the sides of the ramp (fig. 7-1, item 1). A removable stop link is provided on each side to limit ramp travel when the ramp is to be lowered to the horizontal position. If the ramp is to be lowered to the ground for ground loading (fig. 7-12), the stop link must be disconnected. The links can then be pushed up into a stowage tube which has a stowing clip inside at the top of the tube. This clip also holds the link when the ramp is in the fully UP position. On some aircraft that are not modified, two sets of five locking hooks lock the ramp in the CLOSED position. On those aircraft that are modified, two sets of five pins lock the ramp in the CLOSED position. One set is used on each side. Each set of locking pins is actuated by a hydraulic cylinder which pushes or pulls a train of rods to which the pins are attached. The pins slide through blocks located along the sloping longeron and mating clevises on the cargo ramp.

Ramp Opening in the Air. To open the ramp in the air (fig. 7-13), the pressure door must be in the OPEN position. When the pressure door is in the up and locked position, the pressure door uplocked limit switch is actuated. This allows power from the touchdown relay to pass through the energized contacts of the pressure door uplocked limit switch, through the open relay, through the ramp unlocked limit switches to the up solenoid of the ramp actuator selector valve. The ramp is then pressurized up. At the same time power is supplied to the unlock solenoid of the ramp actuator selector valve, and the ramp locks are unlocked. This action closes the ramp unlock limit switches to the lower (open) solenoid of the ramp actuator selector valve. The ramp can then be lowered to the horizontal position. On the ground, power is supplied through the open relay to a ramp height switch. This switch supplies power to either the up or downside of the ramp actuator selector valve. Thus, if the ramp stop links are disconnected, the ramp can be lowered to the ground for ground loading or adjusted to an intermediate position. To close the ramp, power is supplied to one of the ALL DOORS switches. Placing the switch in the CLOSE position energizes the close relay. Power is then supplied to the ramp actuator up solenoid and the ramp is raised (closed). When the ramp is fully closed, the ramp up limit switch is closed to supply power to the lock solenoid of the ramp locking selector valve. On aircraft not modified by a time compliance technical order (TCTO), the ramp lock actuators rotate locking hooks to lock the ramp in the fully UP position. On aircraft modified by a TCTO, the ramp lock actuators push lock pins forward through blocks mounted on the sloping longerons and mating clevises on the cargo ramp to lock the ramp in the fully up position.

Exercises (671):

1. The ramp, like the petal doors and pressured door, receives power to close the doors through the _______________ switches.

2. In order for the ramp to be opened, what door must be opened first?

3. What prevents ramp travel when the ramp is to be opened to the horizontal position?

4. If the ramp must be lowered to the ground for ground loading, the _______________ links must be disconnected.

5. On the ground, power is supplied through the _______________ relay to a ramp height switch.

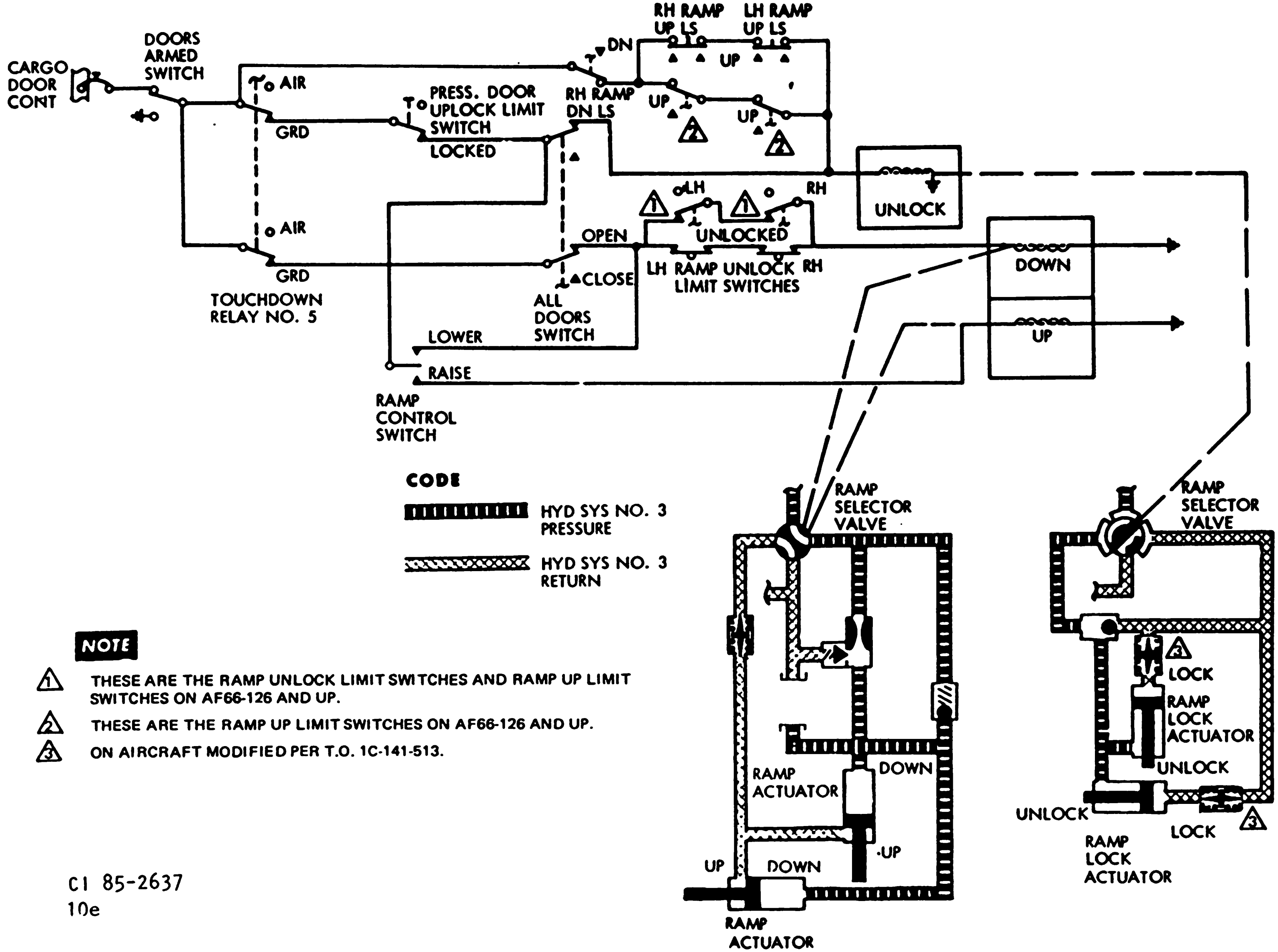


Figure 7–12. Ramp ground operation (open).

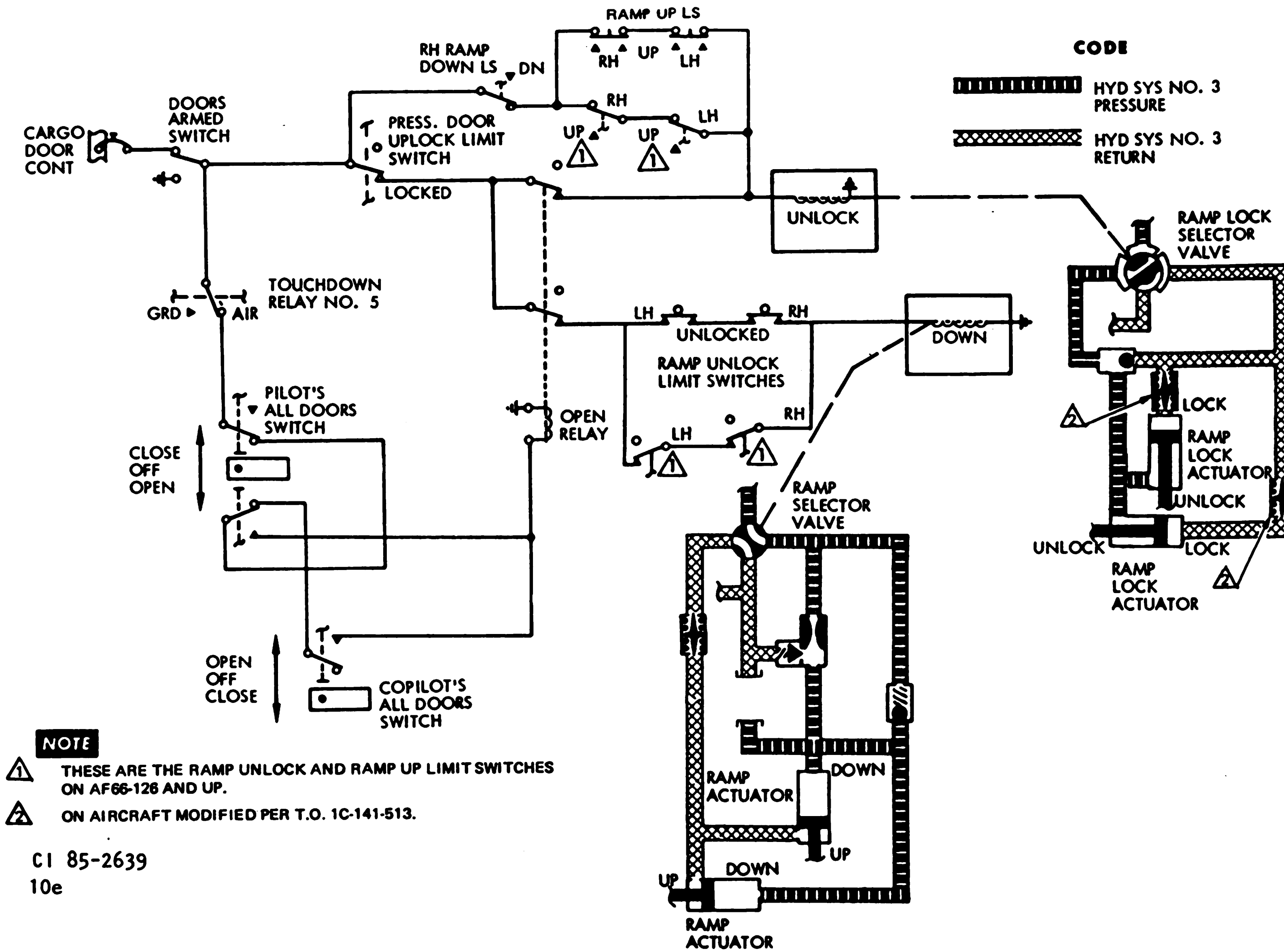


Figure 7–13. Ramp air operation (open).

7-2. Manual Operation

In the previous section we discussed the operation of the cargo door system by means of operating the doors through a set of switches mounted on the various control panels. The maintenance of the different types of components in the cargo system warrants the operation of the door system with a means other than with electrical power operating the different selector valves. This method is through the manual operation of the selector valves in the cargo compartment. We will start with the manual operation of the pressure door, but the same application applies to all selector valves in the cargo door system.

672. Specify the procedures for the manual operation of the pressure door.

Manual Operation. The pressure door, as previously explained, is provided with a single uplock actuator, a pressure door actuator, two downlock actuators, a lock selector valve, and a door actuator selector valve. These selector valves make it possible to perform maintenance on the pressure door system as a separate unit. They allow you to depress the hydraulic portion of the solenoid-operated selector valve with no electrical power applied to the selector valve for maintenance purposes. As long as hydraulic pressure is available to the valve, it can be operated (fig. 7-1A, item 10). Follow these procedures to operate the pressure door manually:

(1) In operating the selector valve you must first manually select the door to the DOWN or CLOSE position in order to release the door from the downlocks. The pressure is ported to the close side of the pressures door actuator to allow the locking hooks to mechanically unlock the ramp fittings before the selector valve of the pressure door actuator is operated.

(2) You must then manually select the downlock selector valve to the UNLOCK position to release the locks from the pressure door.

(3) You are now ready to manually select the doors to open aft and up by selecting the open side of the pressure door selector valve to open. This causes the fluid to be ported to the retract side of the pressure door actuator and the pressure door moves to the OPEN position.

(4) Once the pressure door is in the fully OPEN position, fluid is trapped in both lines to the actuator. You may now select the uplock side of the uplock selector valve to the LOCK position. This causes the locks to lock the pressure door in the UP or OPEN position. To close the pressure door you must reverse the sequence of steps with the last procedure being to depress the pressure door lock selector valve to the LOCK position.

Exercises (672):

1. Prior to opening the pressure door through the use of the manual override, you must first insure that the door is selected to what position?

2. Why are manual override or selector valves used?

3. Once the pressure door is in the fully UP position, what selector valve is used to maintain it there?

4. What prevents the pressure door actuator from closing once the selector valve is released?

673. Specify the procedures for the manual operation of the petal doors.

Manual Petal Door Operation. The petal door selector valves work similar in operation to the pressure door selector valves in operation except the fluid is ported to different components. A set of doors are installed in the underside of the aft fuselage to open and provide a complete aerodynamic fairing over the aft fuselage opening. The doors are actuated by a single hydraulic drive motor and dual jackscrew torque tube arrangement. Two hydraulically actuated latching mechanisms are provided on the lower inboard edge of the left-hand door. When attempting to open the petal doors insure that the pressure door is in the UP or OPEN position to insure complete visibility while operating the doors. Failure to insure that the doors are open could result in serious damage to personnel and equipment. Follow these procedures to operate the petal doors manually:

(1) To open the petal doors you must first select the petal door selector valve to the CLOSE position. This action ports fluid to the retract side of the actuator causing the actuator to retract and allowing the locks to be released.

(2) Next you must select the petal door UNLOCK selector valve to the unlock position. This ports fluid to the extend side of the unlock actuators, which extend to allow the locks to be released from the doors.

(3) Once the locks are released from the doors, the door selector valve is depressed to extend the petal doors. This action ports fluid to the extend side of the petal door actuators to allow the doors to open. On the ground the petal doors may be opened to an 80° position. In flight, the petal doors cannot be opened over 55°. In order to close the petal doors, you must reverse the sequence of operation with the last step being to depress the lock side of the petal door lock selector valve.

Exercises (673):

1. What components are used to open the petal doors?

2. Which selector valve is used to open the petal doors?

3. What is the only position the petal doors can be opened to while the aircraft is in flight?

4. Once the petal door locks have been released, what is the next step in opening the petal doors.

674. Specify the procedures for the manual operation of the ramp cargo door.

Manual Ramp Operation. The cargo ramp is actuated by two hydraulic cylinders that receive pressure through a ramp door selector valve. Ramp lock selector valves are also incorporated to lock the ramp in the UP position. If the ramp is to be lowered to the ground for ground loading, the stop links must be disconnected. The pressure door must be in the OPEN position.

(1) The ramp door selector valve close side is depressed to pressurize the ramp actuator. This action ports fluid to the upside or retraction side of the ramp actuators to prepare the door to be opened.

(2) You must then depress the ramp unlock side of the lock selector valve. This action ports fluid to the downside or extend side of the ramp actuators, allowing the ramp door to extend to the desired position. In order to close the ramp door you must reverse the sequence and end the sequence by depressing the lock side of the door lock selector valve.

Exercises (674):

1. When opening the ramp, what step in the sequence is used to unlock the lock selector valve allowing the locks to release the ramp?

2. What component in the ramp system causes the ramp actuator to both open and close?

3. What is the purpose of the ramp selector valves?

4. When depressing the close side of the ramp selector valve, where does the fluid for the ramp actuator come from?

5. After the ramp has been fully closed using the manual selector valve, what is the next sequence if the ramp operation has been completed?

675. Given hypothetical situations on the cargo doors, determine the malfunctions that may occur.

Troubleshooting the Cargo Door System. The general troubleshooting techniques and procedures that we have already discussed are the same techniques and procedures that you use in troubleshooting the cargo door hydraulic and electrical systems. However, this section provides additional knowledge on specific hydraulic and electrical troubles that you may encounter. As you perform any maintenance task to correct a trouble, make sure you follow the procedures in the applicable TO. Also, observe all safety precautions and make the required entries in the maintenance forms when you complete the work. A set of five indicating light assemblies, located on the pilot or copilot's side console, indicate the position of all cargo door systems, to assist you with troubleshooting.

The first problem you may encounter is that the pressure door will not open using the ALL DOOR switch on either control panel with the aircraft on the ground. Since the doors are actuated by hydraulic pressure, you should check the hydraulic system for proper pressure. By similar reasoning, the doors may be improperly sequenced as a result of maintenance performed on the individual doors. You may have to resequence the doors through the use of the manual selector valves located in the aft cargo compartment, left side of the aircraft looking forward. A third cause or trouble may be that the door locks may not actuate when the doors are selected to open or close. This can be caused by insufficient pressure at the particular door selector lock actuator.

Now let's look at some of the problems you may encounter in the cargo door electrical system. With the doors armed, the ALL DOORS switch actuated to the OPEN position, and the pressure door fails to operate, what would be the probable cause? Remember that the doors are actuated in sequence and before one door opens it must go through a set of switches to sequence the rest of the doors. Electrical power must be available to the door selector valves in order to set the switches in motion. As in the previous malfunction, one of the probable causes is that the open side of the selector valve is probably burned out, which prevents the selector valve from sending pressure to the uplock actuator. With no pressure to the actuator the sequence for the doors will not take place. Another problem that you may encounter is that with the ramp door fully extended, and the ALL DOORS switch selected to the CLOSE position, none of the doors close. Again, in order for the doors to close, the door switches must be activated to port fluid to the selector valves and actuators. With the ramp fully extended you will not be able to mate the switches so you must use the ramp door switch to bring the ramp door to the horizontal position prior to using the ALL DOORS switch. As stated earlier in this section, by-pass switches are located on the door and ramp control panel to test the pressure door, ramp, and petal doors, and petal doors lock lights to assist you in troubleshooting the door system. Be sure to test these lights when troubleshooting the system to make sure that a problem does exist. Remember that in order to correct a problem a problem must exist. Insure that all technical data is used while

performing maintenance of any kind and do not hesitate in asking your supervisor for assistance on problems you may encounter and cannot resolve.

Exercises (675):

1. What is the purpose of the by-pass switches located on the ramp control panel?

2. With the ALL DOOR switch armed, and the ALL DOOR switch selected to open, the doors failed to open. What is the probable cause?

3. Why must you resequence the ramp door after it has been completely lowered to the ground?

4. The pressure door will not open using the ALL DOOR switch, what is the probable cause?

5. Why may it be necessary for you to resequence the doors after door maintenance?

7-3. Test Stands

This section is designed to fulfill two objectives: (1) to familiarize you with graphic symbols associated with hydraulics and (2) to familiarize you with the new Filco and Avitech test stands. The schematic diagrams on the new Filco and Avitech test stands are in graphic symbols.

676. Using a schematic of graphic symbols associated with hydraulics, identify cited symbols and state specified operating characteristics.

Graphic Symbols. For many years the electrical field has had standardized symbols which indicated specified items in a circuit. For example, the symbol for ground, resistance, light, or a switch is basically the same from one electrical schematic to another. Unfortunately, in the pneudraulic field this has not been the case. For instance, the manufacturer of a particular aircraft would draw symbols of hydraulic components, interconnect them with lines, and give a brief description of how the system operated. This is fine if you work on that particular aircraft as long as you are in the service. But we know this is impossible.

To simplify the reading and standardize fluid diagram schematics, graphical symbols have been designed to keep current with the latest state-of-the-art in hydraulic components. The graphic symbols we will be talking about conform to the United States of America Standards Institute U.S.A.S.I. system. You may also encounter similar systems that have been adopted, but if understand the U.S.A.S.I. system, you will be able to interpret the others. The U.S.A.S.I. symbols are designed to eliminate the use of letters; so they are capable of being used by other countries that do not speak English. This then is a universal language in graphic form. With this type of universal system, you should be able to pick up any schematic that uses graphic symbols and be able to fully understand the system operation. Graphic diagrams do not attempt to show how components are constructed, only how they function and their connection within the circuit. You could compare graphic symbols to the shorthand that a secretary uses. Once the symbols are known and understood they are much easier to understand and faster to work with.

The graphic symbols shown in figure 7-14 are only samples of the symbols used in a circuit. Before describing the symbols and telling how they are used, let's discuss basic rules which are applicable to graphical symbols for fluid diagrams.

- Symbols do not indicate location of ports, direction of shifting of spools, or position of control elements on actual components.
- Symbols may be rotated or reversed without altering their meaning and may be drawn any size for emphasis or clarity.
- Each symbol is drawn to show normal or neutral condition of component unless multiple circuit diagrams are furnished showing various phases of circuit operation.
- Arrows used within symbol envelopes show direction of fluid flow in a component as used in the application represented. Double-end arrows indicate reverse flow.

Now refer to figure 7-14 again as we discuss each of these symbols. Lines—pressure, suction, or return—are drawn as a solid line. Pilot and drain lines are drawn as broken lines. Hoses are drawn as a fuse in an electrical circuit. To show that two lines cross each other but do not join, a loop in one of the lines will be used. When two lines join each other, a dot is placed at the point of intersection. A rectangle is the symbol for a reservoir. If the reservoir is unpressurized, the top will be open. In many cases, rather than draw a return line back to the reservoir, the reservoir is placed next to the component's return port. This eliminates having to draw return and drain lines back to the reservoir. The reservoir then may be drawn in several places in the schematic, although in reality there is only one reservoir. A circle, with a black triangle pointing in the direction of fluid flow, is the symbol for a hydraulic pump. An arrow drawn through the pump indicates that the pump is a variable volume pump. If the pump is compensator-controlled, then a small box is placed to the side of the circle. A check valve is shown as a ball sitting between two lines which are at a 90° angle from each other. The direction of free flow will be as shown in figure 7-14. A restrictor is shown as two half-moon-shaped lines which oppose each other. An orifice check valve will be shown with a box called an enclosure. An enclosure is used to show the limits of a component which contains more than one unit. The enclosure is shown with long-and-short dashes around these units. A relief

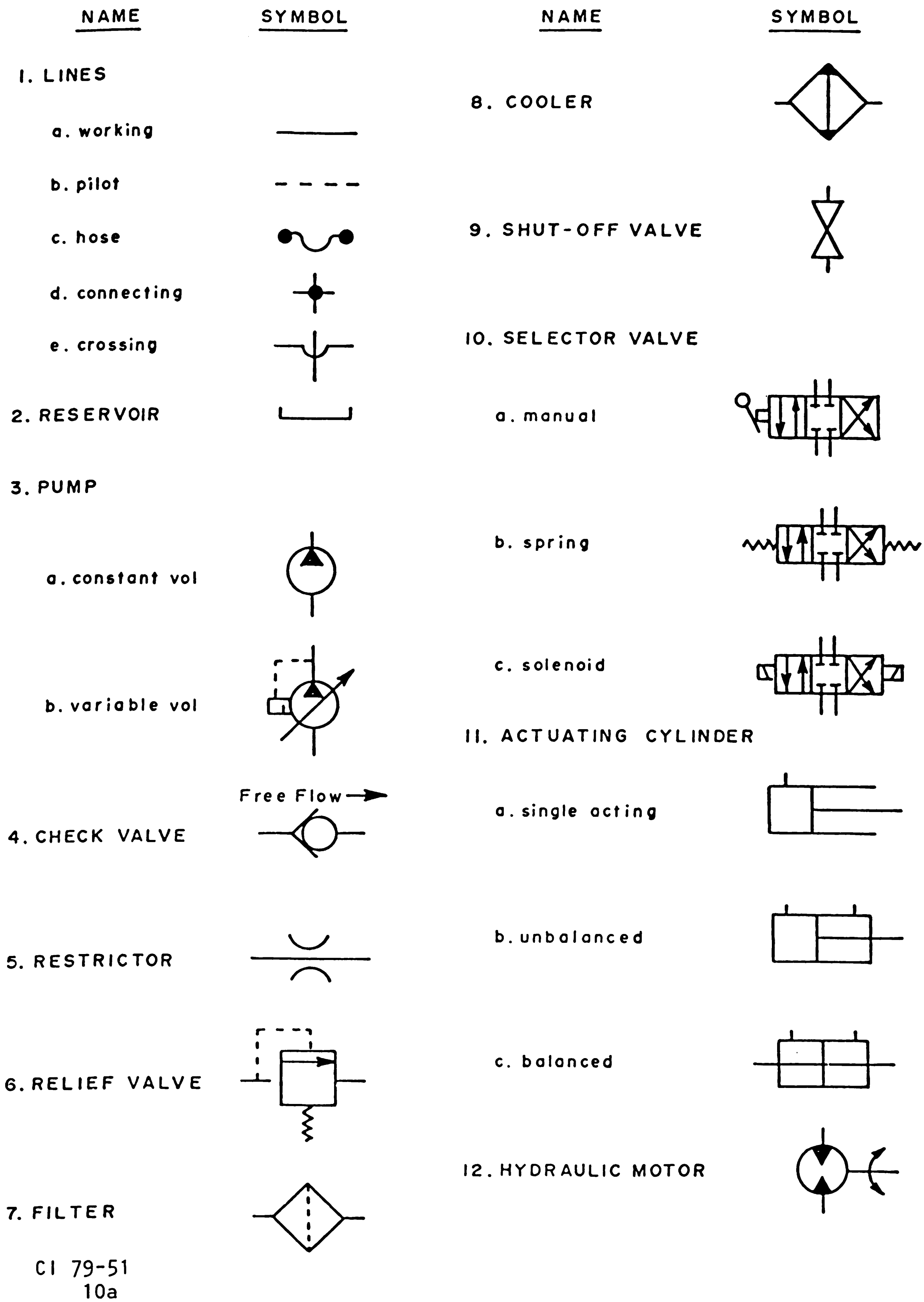


Figure 7–14. Graphic symbols.

valve is shown as a square with an arrow inside to show the direction of flow. A spring is used to keep the arrow to one side until pressure from the pilot line can offset the spring. A filter is shown as a box with a dotted line down the center. The symbol for a heat exchanger or cooler is basically the same as that for the filter. The two dark areas of the cooler are actually arrows which indicate the direction the heat is traveling. In this case, the heat is traveling away from the fluid line. A shutoff valve is shown as a simple hourglass-shaped object. A selector valve uses a multiple envelope system that has a separate rectangle for each position. All the port connections are made to the envelope that shows the neutral condition of the valve. Within each envelope are arrows showing the flow when the valve is shifted to that position. As an example, a two-position valve will have two envelopes, whereas a three-position valve will have three envelopes. The control symbol (manual, spring, or solenoid) is placed to either side of the envelopes. An actuating cylinder is shown as a rectangle with a horizontal and vertical line inside which indicates the piston and rod. A hydraulic motor is shown as a circle with dark triangles pointing toward the center of the circle. The direction of the motor is indicated by the arrows on the side of the motor. The motor shown in figure 7-14 can rotate clockwise and counterclockwise.

Exercises (676):

Using figure 7-15, answer the following questions relating to graphic symbols.

1. What must the return fluid pass through before it returns to the reservoir from the actuating cylinder?

2. When the selector valve is positioned to extend the actuating cylinder, the fluid must pass through which type of unit?

3. In which position should the selector valve be positioned to retract the actuating cylinder?

4. What does the box with dashed lines in the extend line of the actuating cylinder indicate?

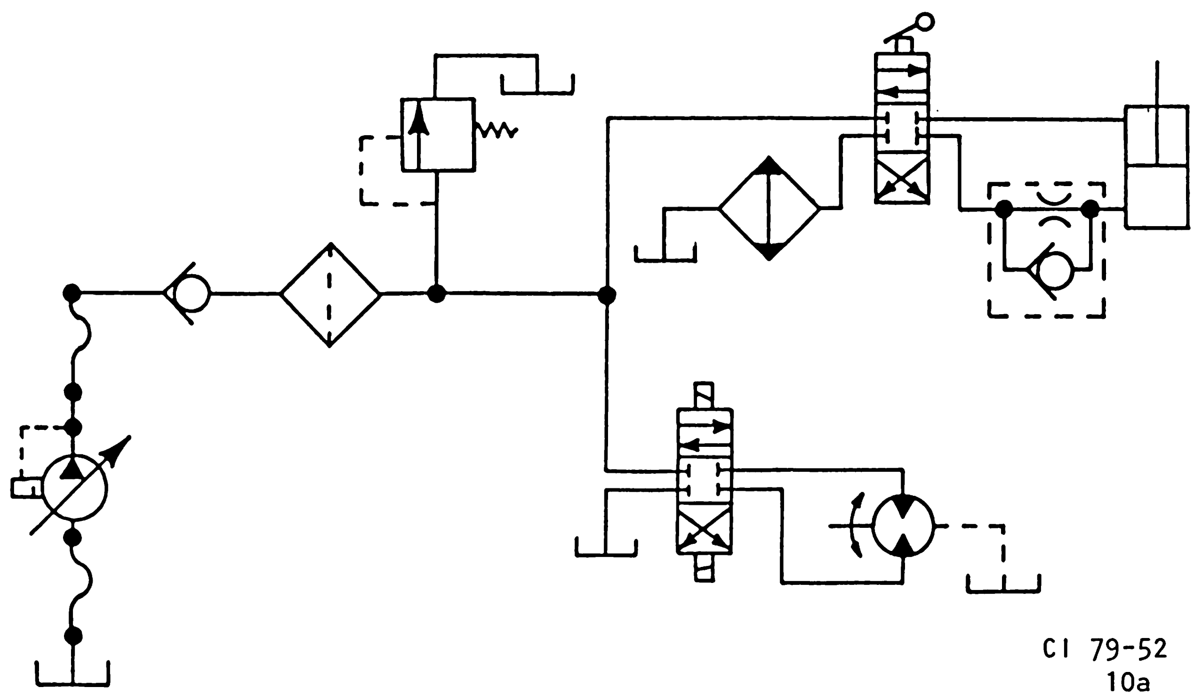


Figure 7–15. Graphic flow diagram.

5. The hydraulic motor can be rotated in which direction?

6. What type of pump is used to produce the fluid flow into the system?

677. Identify operational characteristics of the Filco test stand, and specify functions of various circuits.

Now that you have a general idea of graphic symbols, we'll briefly mention another test stand that also is replacing the HCT–6 test stand—the Avitech. This is the newest test stand to arrive in the field and is similar in design and operational features to the Filco. Therefore, we will concentrate our efforts on the Filco.

Filco Test Stand. The Filco test stand, shown in figure 7-16, is replacing the HCT–6. The Filco test stand is made up of two separate units. The drive console (A) is used to mount hydraulic pumps so they can be tested. It consists of a variable speed drive incased in a plastic shield. The main unit (B) is divided into two other sections. The extreme right hand side of the main unit is called the control console (C); it contains the electrical controls and electrical components. The left hand side (D) of the main unit contains most of the hydraulic controls and gages.

Test Stand Circuits. The test stand consists of seven circuits: suction, boost, high pressure, static pressure, return, air supply, and high pressure nitrogen. Refer to figure 7-17 as we go through the theory of operation of each of these circuits. We'll start with the reservoir and work from there. The reservoir (1) supplies fluid to the various circuits; in this case it supplies fluid to the boost pump (11) and to the hydraulic booster (57). The boost pump (11), driven by a 5-hp motor, pumps fluid through the heat exchanger (12), filter (20), to the boost pressure relief valve (52), boost supply outlets (54) and (54A). Boost supply outlet (54) and (54A) are used to supply fluid for testing an external pump when it is connected to the variable speed drive of the drive console. The boost pump also sends fluid to an electrical motor-driven high pressure pump (24). The high pressure pump outlet forces fluid under high pressure to the high pressure circuit. This circuit is used to check components dynamically. Notice that the high pressure pump (24) sends fluid to the relief valve (29) and to the cycling valve (34). The cycling valve is nothing other than a manually operated selector valve which will route the fluid to and from the cycling ports (35). The return circuit consists of all the lines interconnected together to route the fluid back to the reservoir (1). Before the return fluid can enter the reservoir, it must pass through a filter (55). Static testing of various components is done with the static pressure circuit. The hydraulic booster (57) supplies the high hydraulic test pressure for the parts under static test. The hydraulic booster is capable of delivering 25,000 psi of hydraulic test pressure when 80 psi of shop air is supplied to the hydraulic booster. The shop air inlet port (66) sends the air to the booster unit through valve (65), air regulator (59) and air line lubricator (58). As you can see in figure 7-17, the suction line supplies fluid from the reservoir (1) to the boost unit (57). When a component is to be tested statically with the static pressure circuit, it will be connected to outlet port (78). The high pressure nitrogen circuit is supplied with nitrogen from the nitrogen cylinder (68). High pressure nitrogen stored in the cylinder can be used for testing aircraft components that must be tested by nitrogen and for reservoir pressurization.

We have already stated that when an external pump is being tested on this test stand, fluid is supplied to the pump under test through posts (54) and (54A). Fluid produced by the pump under test will flow back to the test through port (36A) to relief valve (40) and throttling valve (41). With the throttling valve closed pressure will register on gage (33). When the throttling valve is open, fluid from the pump under test will flow through either flowmeter (45) or (46) back to return. The case drain line from the pump being tested is connected to case drain return port (51). Fluid then flows through the case drain flowmeter (47) back to return.

The heat exchanger uses water to keep the fluid temperature between a specified amount. The cooling water comes in through port (16); then it will pass through a temperature control valve (13) before it enters the heat exchanger. The fluid temperature controller (17), which is supplied with air pressure from the air supply circuit, will open and close the temperature control valve (13).

Exercises (677):

Answer the following statements true or false by placing the letter T for true and the letter F for false in the blank space before each statement. Use figure 7-17 to aid you in answering the questions, and correct any false statements.

____ 1. The suction circuit supplies fluid to the low pressure boost pump and the hydraulic booster.

____ 2. The pressure buildup in a static pressure circuit is generated by the main high pressure pump.

____ 3. The air supply circuit provides the air for the operation of the hydraulic booster.

____ 4. The hydraulic booster delivers 25,000 psi hydraulic test pressure.

____ 5. The cycling valve (selector valves) receives the supply of fluid from the high pressure circuit.

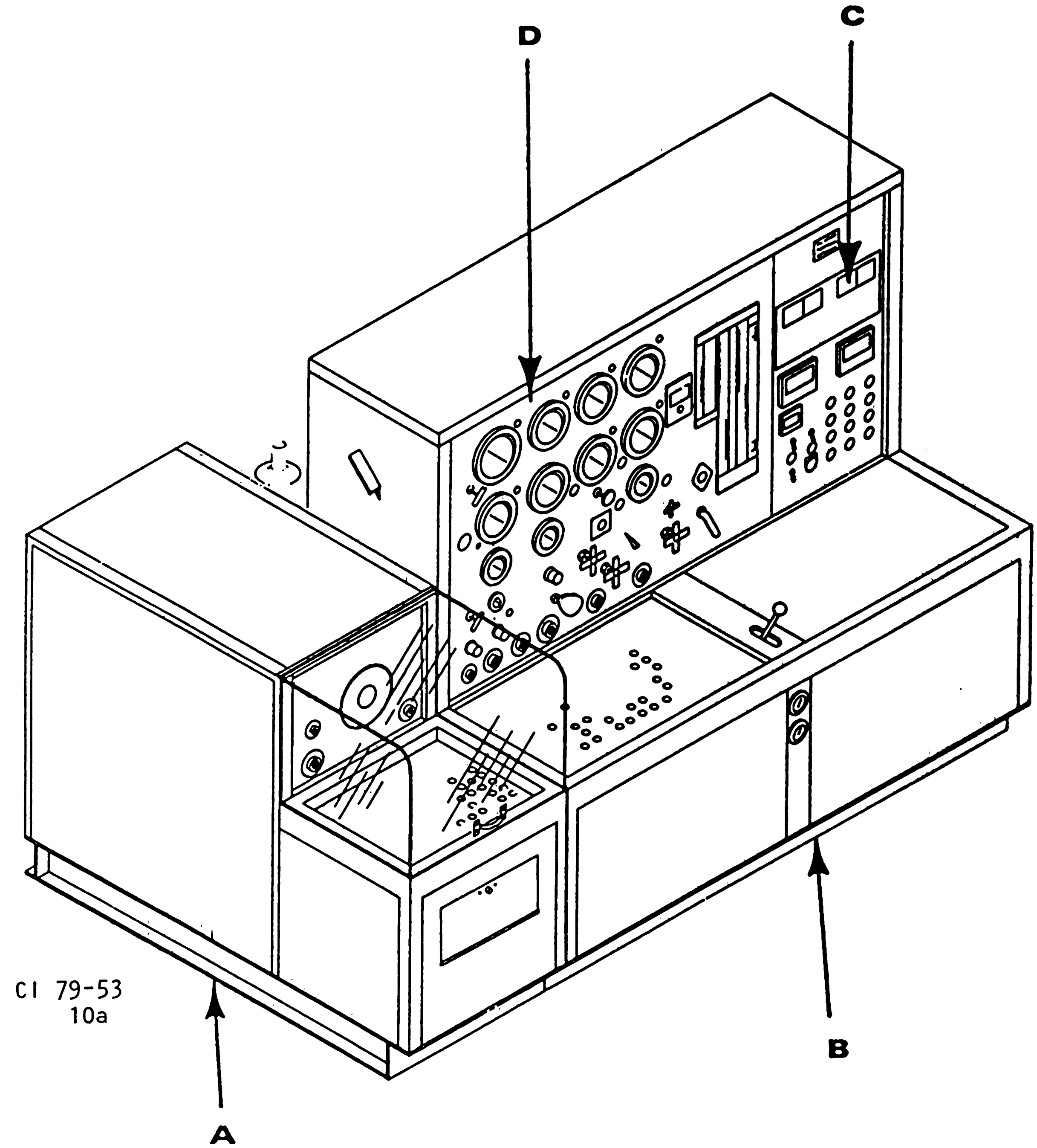
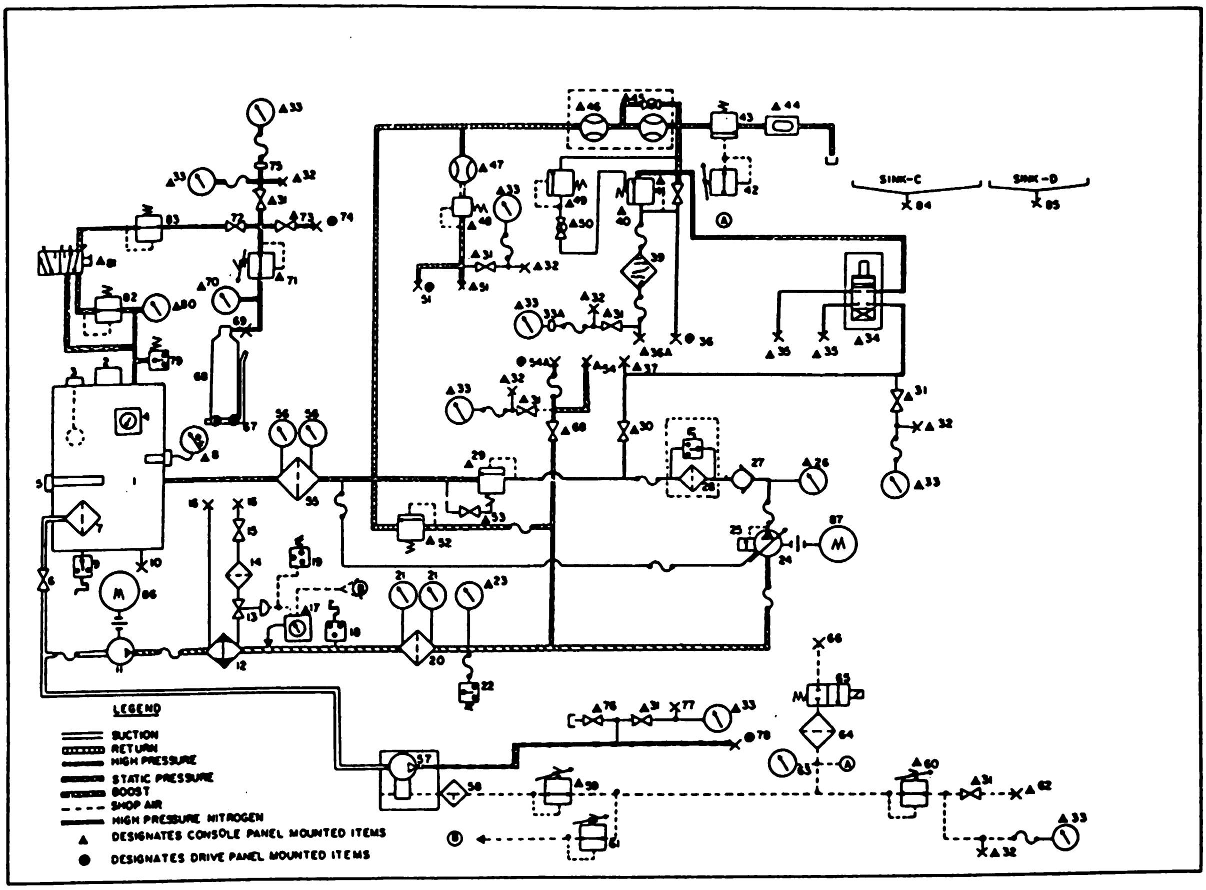


Figure 7–16. Filco test stand.



1. Reservoir
2. Filler Cap
3. Low Level Switch
4. Liquid Level Indicator
5. Immersion Heater
6. Suction Shutoff Valve
7. Sump Filter
8. Reservoir Tempera— ture Indicator Gage
9. Temperature Switch
10. Port
11. Boost Pump
12. Heat Exchanger
13. Temperature Control Valve
14. Strainer
15. Valve
16. Water Ports
17. Fluid Temperature controller
18. Temperature Switch
19. Pressure System
20. Filter
21. Low Pressure Filter Gage
22. Pressure System Boost Switch
23. Boost Supply Pressure Gage
24. High Pressure Pump
25. High Pressure Pump Pressure Compensator
26. High Pressure Pump Discharge Pressure
27. Check Valve
28. Filter
29. High Pressure System Relief
30. High Pressure Outlet Shutoff
31. Valve
32. Calibration Ports
33. Pressure Gage
34. Cycling
35. Cycling Ports
36. Test Pump Discharge
36A. Return
37. High Pressure Outlet
38. No Item
39. Ripple Filter
40. Discharge High Pressure Control
41. Discharge Throttling
42. Relieve Type Regulator
43. Relief Valve
44. Flowmeter Over Pressure
45. Flowmeter Bypass
46. Discharge Flow
47. Case Drain Flowmeter
48. Case Drain Back Pressure Regula— tor Valve
49. Discharge Low Pressure Control
50. Discharge Pressure Cycling
51. Case Drain Return
52. Boost Pressure Relief
53. High Pressure System Dump
54. Test Pump Inlet
54A. Boost Supply Outlet
55. Filter
56. Pressure Gage
57. Hydraulic Booster
58. Air Line Lubricator
59. Air Operated Pump Regulator
60. Air Supply Pressure Regulator Valve
61. Air Supply Pressure Regulator
62. Air Supply Outlet
63. Pressure Gage
64. Air Supply Moisture Separator filter
65. Solenoid Valve
66. Shop Air Inlet Port
67. Cylinder Cart
68. Nitrogen Cylinder
69. Cylinder Outlet
70. Nitrogen Pressure Gage
71. N_2 Supply Pressure Regulator
72. Valve
73. N_2 Test Outlet Shutoff
74. N_2 Test Outlet
75. Gage Saver
76. Static Test Bleed
77. Calibration Port
78. Static Test Outlet
79. Reservoir Pressure Switch
80. Reservoir Pressure
81. Reservoir Pressure
82. Nitrogen Regulator
83. Regulator
84. Port
85. Port
86. Motor
87. Motor
88. Valve

CI 79-54
10a

Figure 7–17. Filco test stand flow diagram.

____ 6. The static test pressure pump delivers fluid to the circuit for checking out external power pumps.

____ 7. The cooling water for the heat exchanger enters the unit through inlet 66.

2. Match the test stand circuit to its function. Place the letter in the circuit column in the blank space provided for it alongside the circuit function.

Circuit Functions

____ (1) Generates high pressure in the static pressure circuit.
____ (2) Delivers fluid pressure for dynamic testing of hydraulic components.
____ (3) Supplies fluid to the high pressure pump.
____ (4) Supplies fluid to the individual circuits.
____ (5) A series of interconnecting lines which collects fluid and routes it back to the reservoir.
____ (6) Uses a storage bottle.
____ (7) Supplies the pressure for building the pressure in the static test circuit to 25,000 psi.
____ (8) Utilizes the cycling valve for dynamically testing components.

Circuits

a. Suction circuit.
b. Low pressure hydraulic circuit.
c. High pressure hydraulic circuit.
d. Static pressure circuit.
e. Return circuit.
f. Air supply circuit.
g. High pressure circuit.

Answers for Exercises

CHAPTER 1

References:

600 – 1. A vent line filter.
600 – 2. Because of the vibration of the pump. If a metal line were installed, it would eventually fail.
600 – 3. Suction boost pump.
600 – 4. For cooler operation.
600 – 5. Low pressure.
600 – 6. By the indicator on the filter assembly.
600 – 7. Check valve.
600 – 8. Fire control tee handle, which will close off the supply of fluids to the pumps.
600 – 9. To cool the fluid in the system.
600 – 10. (1) Fire tee handle.
(2) Engine pump switch.

601 – 1. The reservoir is pressurized by system operation pressure.
601 – 2. To make it easier to remove and install the pump.
601 – 3. For pump vibration.
601 – 4. It reduces the natural ripple produced by most piston-type pumps.
601 – 5. Low system pressure.
601 – 6. Case drain of the pump.
601 – 7. By thin tubing between the fuel and hydraulic system.
601 – 8. To the system manifold.
601 – 9. (1) Filter assembly.
(2) Quick disconnect.
(3) Check valve.
(4) Relief valve.
601 – 10. Fuse.

602 – 1. Since the pressure switch and pressure indicator both show low or no pressure, you can assume that the pressure is low and these items are working properly. Some of the things that could cause this are bad pump, clogged filter, low supply of fluid, or relief valve improperly adjusted.
602 – 2. Since the pressure switch stayed out, you should check the system pressure with the direct reading gage on the accumulator. If the gage indicates normal, you can suspect that some unit in the pressure indicating system is bad. This could be the transmitter, the snubber clogged or in the indicator itself.
602 – 3. Low supply of fluid could cause this to happen or the low suction pressure switch could be bad.
602 – 4. You should have checked the circuit breaker first. Changing the light bulb should have been next.

603 – 1. The air compressor would not be lubricated properly and may be damaged.
603 – 2. Auxiliary air regulator.
603 – 3. It will come out the drain on the access door.
603 – 4. The thermostat heating blanket.
603 – 5. Air servicing valve filter and direct reading pressure gage.
603 – 6. A filter in the dump valve port.
603 – 7. The hydraulic flow regulator between the hydraulic control valve and air compressor.
603 – 8. (1) The hydraulic control valve.
(2) The dump valve solenoid.

604 – 1. Servicing markings on the aircraft.
604 – 2. Besides using the TO, the pressure should be depleted.
604 – 3. Check the air charge in the accumulator.
604 – 4. The pressure should be decreased. The reason why is that when the temperature rises, the gas will expand.
604 – 5. The technical order and data plate.
604 – 6. (1) The type of fluid that should be used.
(2) The position of the system.
(3) The pressure that must exist before servicing.
604 – 7. The reservoir may burst because of the large volume of fluid being pumped into the reservoir.
604 – 8. (1) The subsystems in the wrong position.
(2) The accumulator charged with fluid pressure.
604 – 9. By looking at the filter indicator button.
604 – 10. Leakage and security of mounting.

605 – 1. (1) a.
(2) c.
(3) b.
(4) a, b.
605 – 2. a. Check it against the accumulator gage or install a pressure test gage.
b. Before running the engine, you should have the proper TO. By looking in the TO, you could have answered the pilot's question.
c. You should have insured that the reservoir was serviced properly before running the engines.

606 – 1. (1) Pump pressure.
(2) Supply.
(3) Shaft seal drain.
(4) Case drain.
606 – 2. To remove the air in the pump. If the air is not removed, it could damage the pump during operation.
606 – 3. To make it easier to install and to prevent the splines from wearing.
606 – 4. The hydraulic test stand cannot pressurize the aircraft pump. The engines will have to be run.
606 – 5. Deplete the pressure in the system. Next remove the filter bowl and remove the old element. Replace all O-ring seals. Install the new element and then the filter bowl.
606 – 6. To eliminate the air in the system.
606 – 7. In the TO or in some cases printed on or near the filter bowl.
606 – 8. That the system is contaminated.
606 – 9. The air will not pass through the cartridge.
606 – 10. The cartridge is installed so that the arrow and the word "flow" is pointing in the direction of the outlet port.

607 – 1. By taking a sample of the fluid and performing a contamination test. Another way is to look at the color of the fluid.
607 – 2. Because some units cannot be drained properly by disconnecting the lines to it.
607 – 3. Because many of the valves or units would prevent the fluid being used for flushing to pass freely through them.
607 – 4. Purging is used primarily with pneumatic systems. It is defined as the cleansing of a system.
607 – 5. Condensation.

608 – 1. The pressure line shut-off should be open.
608 – 2. Compensator (pressure) setting.
608 – 3. It should be closed and pump production zero flow.
608 – 4. Case drain port.

609 – 1. Insure that the air pressure is released.

609 – 2. By using the magnetic particle inspection.
609 – 3. More than likely, the shell was damaged during disassembly. If the accumulator is not held properly during disassembly, the shell may be distorted.
609 – 4. No, as long as the face of the piston is toward the hydraulic end cap.
609 – 5. By bubbles in the hydraulic fluid.

CHAPTER 2

610 – 1. Tricycle and quadricycle.
610 – 2. So that the landing shock is distributed as widely as possible throughout the main body of the structure.
610 – 3. a. Forward visibility for takeoff and taxiing was improved.
b. Ground looping was eliminated.
c. Hard application of brakes without fear of noseover.
610 – 4. Multiple-axle (bogie) truck-type main landing gear.
610 – 5. Weight displacement and tire size.
610 – 6. Lateral stability during heavy gross weight landings.
610 – 7. Four main gears mounted in the fuselage in the form of a rectangle and two outrigger or tip protection gears.
610 – 8. Because it is used only on the B–52 aircraft.
610 – 9. Allows for thinner wing design and therefore greater speed. Landing forces are more evenly distributed over the whole aircraft. Makes use of shorter, yet larger, main landing gear assemblies.

611 – 1. To prevent accidental collapsing of the landing gear while the aircraft is on the ground.
611 – 2. Pulled away from the control handle.
611 – 3. Electrical circuit is open.
611 – 4. Pull the lock release finger latch down.

612 – 1. A picture of a barber pole.
612 – 2. When the pilot forgets to lower the gear during landing procedures.
612 – 3. By pushing the warning horn silence button.
612 – 4. Whenever the landing gear is between the DOWN or UP and LOCKED position.
612 – 5. Left main gear indicator will show a wheel, right main gear indicator will show the word UP, and nose gear indicator will show a barber pole.

613 – 1. No. Electrical power goes directly to the control valve and ground, and the sequence switches are not used for gear extension.
613 – 2. A hydraulic motor that turns a gearbox.
613 – 3. The gearbox brake.
613 – 4. Manually by a hand crank.
613 – 5. Deplete all hydraulic pressure before actuating the emergency system.
613 – 6. The nose gear is locked in the UP position by an uplock cylinder and in the DOWN position by an internal lock built into the actuating cylinder.
613 – 7. The NLG emergency extension valve is placed in the EMERGENCY position.
613 – 8. A 2-way flow regulator.
613 – 9. A shuttle valve.
613 – 10. A shuttle valve.

614 – 1. Main gear scissors switch, nose gear limit switch, main gear inboard door close limit switch.
614 – 2. By a sequence valve that is actuated by the rotation of the uplock hook.
614 – 3. By integral down locks built into the actuators.
614 – 4. Deenergized.
614 – 5. It is dumped overboard. High-pressure air from the emergency air bottles actuate a pressure-operated dump valve.
614 – 6. Gear down sides of the drag brace actuator and the uplock actuator.
614 – 7. The uplock mechanism.
614 – 8. It actuates a sequence valve that allows hydraulic fluid to flow to the uplock actuator.
614 – 9. As the down lock limit switch or each actuator breaks contact.
614 – 10. A pin on the strut fork.
614 – 11. A restrictor.
614 – 12. By mechanical linkage.

615 – 1. Used to halt the forward motion of the aircraft if wheel brakes, speed brakes, and drag chute fail to operate.
615 – 2. It controls the flow of hydraulic fluid going to the vertical damper cylinder.
615 – 3. By a spring-loaded uplatch and in the DOWN position.
615 – 4. Air-oil pressure in the top of the vertical damper cylinder and the weight of the arresting hook.
615 – 5. Surge damper.
615 – 6. By a control lever that releases tension from the arresting hook control cable which releases the spring-loaded uplatch mechanism.
615 – 7. A 2-way restrictor.
615 – 8. 1.1 seconds from the time the arresting hook contacts the hook up limit switch.

616 – 1. To the right.
616 – 2. Fluid in the steering cylinders would have to transfer from one cylinder to the other.
616 – 3. A followup action.
616 – 4. Cylinder barrels are stationary, piston rods are movable.
616 – 5. Lower torque link.
616 – 6. The rocker arm.

617 – 1. Command potentiometer and followup potentiometer.
617 – 2. The solenoid in the nose gear steering valve deenergizes and shuts off hydraulic fluid to the steering system.
617 – 3. Prevents cavitation of the vane motor and dampen shimmy when the steering system is not energized.
617 – 4. The steering (command) potentiometer.
617 – 5. The servo valve holds the wheels at the desired degree of turn.
617 – 6. Nose gear down limit switch, right main gear scissors switch, and the landing gear control switch.
617 – 7. Nose gear steering switch.
617 – 8. Bypass valve.

618 – 1. Auxiliary hydraulic system.
618 – 2. Slow-release fail-safe relay.
618 – 3. The emergency selector valve is energized and the normal brake selector valve is deenergized.
618 – 4. The brake control valve.
618 – 5. Both brake selector valves will be positioned to allow operation from either the utility or auxiliary hydraulic system.
618 – 6. Nonrotation and/or a rapid change in wheel speed.
618 – 7. By the locked-wheel detection relays.
618 – 8. The touchdown protection circuit.
618 – 9. Brake pressure releasing valve (antiskid valve).
618 – 10. If you don't, you will bleed away pressure faster than the handpump can be operated.

619 – 1. Antispin system.
619 – 2. Memory locked wheel protection circuit.
619 – 3. By depressing the rudder brake pedals in either the forward or aft cockpit.
619 – 4. The size of the opening of the pressure port in the control unit.
619 – 5. By pulling aft on the emergency brake handles and depressing the rudder brake pedals.
619 – 6. Negative.
619 – 7. Because during emergency operation hydraulic fluid does not flow through the antiskid valve.
619 – 8. Gear up line.
619 – 9. By the movement of the exciter ring through the magnetic field of the sensor.
619 – 10. Enough for 11 to 13 brake applications.
619 – 11. When the aircraft speed is less than 15 knots.

620 – 1. Remove and replace the line and look for the cause of the chaffing.
620 – 2. Leakage, security of mounting, proper adjustment.
620 – 3. Cuts, broken wires.
620 – 4. Wear, overheating, corrosion, leakage.
620 – 5. Adjustment, binding, security of mounting, leakage.
620 – 6. Being broken or cracked.

621 – 1. Step 1, assemble all tools.
621 – 2. Step 5, cap or plug the lines.
621 – 3. Step 3, depressurize hydraulic system.
621 – 4. Step 5, tag the lines to indicate to what ports they should be installed.

621 – 5. New O-ring seals were not installed.
621 – 6. Operational check was not made.

622 – 1. Periodic inspection; when maintenance is performed that might affect gear linkage or adjustment; after a hard landing; or the pilot reports a malfunction.
622 – 2. Hydraulic test stand and an electrical power unit.
622 – 3. It depends on the specific aircraft. Check the applicable aircraft technical order.
622 – 4. High enough to allow the landing gear to safely clear the ground during all operational actions.
622 – 5. Bleed the hydraulic system of air.
622 – 6. Barber pole.
622 – 7. Until the system is clear of air.
622 – 8. After the gears have been cycled a minimum of three times.
622 – 9. To catch any hydraulic fluid that might have poured out during emergency extension.
622 – 10. Prior to applying hydraulic and electrical power.

623 – 1. Instruction plate on the strut near the filler inlet and air valve assembly and in the applicable aircraft TO.
623 – 2. Shock strut must be deflated and in the full compressed position.
623 – 3. Remove all stands, jacks, and obstructions from under the aircraft. Make sure all personnel are clear of the aircraft.
623 – 4. Approximately 450 psi.
623 – 5. To eliminate any binding that might take place between the inner and outer cylinders.
623 – 6. When you cannot get another drop in it without overflowing.
623 – 7. They could cause damage to the aircraft when it is lowered.
623 – 8. It would decrease the shock absorbing capabilities of the strut and could cause the strut to bottom out.

624 – 1. Insure that all air has been released.
624 – 2. The wrong tool was used during assembly or disassembly.
624 – 3. So that the metering pin and orifice are not damaged.
624 – 4. That the strut may be wearing internally.
624 – 5. A fine tooth file should be used to repair the damage.
624 – 6. The integrity and safety of the strut is not guaranteed.
624 – 7. The flat part of the scrapper ring must face toward the top of the strut.
624 – 8. Because of moisture which may cause corrosion and the hazard associated with air pressure.
624 – 9. It is serviced with preservative fluid, and all unpainted or exposed parts should be covered with a corrosion-preventive compound. Then it should be packaged properly to prevent damage to the strut.

625 – 1. Pressure is trapped in the system for shimmy damper operation and will squirt out when the hydraulic lines are loosened.
625 – 2. The system could be contaminated.
625 – 3. Assemble all the tools and equipment needed to remove it.

626 – 1. Neutral 0°.
626 – 2. The nose gear can be positioned without placing too much of a bind on it.
626 – 3. Check the plate that is usually mounted on the nose gear collar.
626 – 4. To allow the centering cams in the nose strut to position the nose gear in the NEUTRAL position.

627 – 1. Air is in the system.
627 – 2. The mechanic did not keep enough fluid in the brake reservoir.
627 – 3. Some fluid was not drained from the brake system reservoir before the bleeding was started.
627 – 4. To prevent system contamination.
627 – 5. To prevent fluid and air from being drawn back into the system from the receptacle.
627 – 6. To the bleeder port on the brake unit.
627 – 7. Until no air bubbles appear and the spongy pedal action is eliminated.

628 – 1. Step 1. d.
Step 2. c.
Step 3. a.
Step 4. e.
Step 5. b.
Step 6. f.
Step 7. h.
Step 8. g.
Step 9. i.
Step 10. j.

629 – 1. You should check for any visible damage to the unit which could cause the malfunction or discrepancy.
629 – 2. So there will be no foreign matter left to contaminate the system when the unit is reassembled and to insure a more accurate inspection.
629 – 3. They should be replaced together or put back in the same place they were removed from.
629 – 4. To make sure it operates properly.
629 – 5. To locate those parts that are bad or doubtful.
629 – 6. The unit supply document number.
629 – 7. When all the parts needed for the repair were not available.
629 – 8. Put the unit with all its parts in an AWP storage bin.

630 – 1. The uplock switch is out of adjustment or has malfunctioned. This caused the circuit to be broken thus deenergizing the landing gear selector valve.
630 – 2. Since the selector valve is common to all gears and the gear switches are not involved in the gear down position, it can only be a brake in the wiring to the selector valve, the landing gear switch, or the landing gear selector valve itself.
630 – 3. You can suspect that the controllable restrictor is out of adjustment or is malfunctioning.
630 – 4. The hydraulic brake or gear box has malfunctioned.

631 – 1. Since these two items are machined parts they should both be replaced if found damaged.
631 – 2. The coils should be checked for continuity by using an ohmmeter.
631 – 3. To show their position during installation.
631 – 4. a. 10 CC per minute.
b. Pressure port.
c. 1 minute.

CHAPTER 3

632 – 1. Steering metering valve through the chain and cable assembly.
632 – 2. By the compensator of the steering metering valve.
632 – 3. Double acting unbalance.
632 – 4. By centering cams in the nose strut.

633 – 1. Shimmy action.
633 – 2. To check for 90 psi back pressure. The back pressure is used for shimmy dampening action.
633 – 3. If the brakes are dragging or the tires improperly serviced, this could cause the aircraft to pull to one side.

634 – 1. Be careful when removing the cap, because of the large spring behind it.
634 – 2. If it is found beyond repair, then it and the shaft (16) will have to be replaced, because they are a matched set.
634 – 3. By polishing with crocus cloth.
634 – 4. By viewing the shaft through port E.
634 – 5. Check for leakage at Port A and around the seals on the shaft.

635 – 1. So the lock (15) can be removed.
635 – 2. For visible evidence of cracks.
635 – 3. It should be polished out with crocus cloth.
635 – 4. Loosen the lockring one turn and adjust the cap on the barrel.
635 – 5. Insure that the lock slot in the trunnion is lined up with the lockslot in the barrel.
635 – 6. 5 minutes.
635 – 7. (1) Flush the assembly with Mil–H–6083 preservative.
(2) Tighten and safety the lockrings.
(3) Plug all ports.

636 – 1. The brakes dragging or power brake control valve out of adjustment.
636 – 2. The inline relief valve could be leaking internally.
636 – 3. By pulling the antiskid circuit breaker. This will eliminate the antiskid system.

637 – 1. It could cause the paint to lift.
637 – 2. Thickness, warpage, wear, and cracks.
637 – 3. Springs and the tube and grip assembly.

637 – 4. The grip and tube.
637 – 5. The rivet must be flush or below the surface of the wear pad.
637 – 6. Retaining approximately 75 psi in the brake while checking for minimum OFF clearance.

638 – 1. Bubble test.
638 – 2. Proof pressure test.
638 – 3. To check the bypass relief valve and differential pressure indicator.
638 – 4. Polish out minor scratches or corrosion with the specified abrasive cloth.

CHAPTER 4

639 – 1. Camber is defined as the curve of the surface of an airfoil from the leading edge to the trailing edge.
639 – 2. Thrust.
639 – 3. Weight (gravitational pull).
639 – 4. Lift.
639 – 5. Drag.
639 – 6. Shape of airfoil.
639 – 7. When the aircraft is in straight and level unaccelerated flight.
639 – 8. Thrust and drag.
639 – 9. By the pressure differential action on the top and bottom of the wing.

640 – 1. Pitch axis.
640 – 2. Rudder.
640 – 3. Ailerons.
640 – 4. Right aileron raised, left aileron down.
640 – 5. Rudder.
640 – 6. On the trailing edge of controls such as the elevator, rudder, and aileron.
640 – 7. Spoilers.
640 – 8. Spoiler.
640 – 9. Used to increase drag to slow the aircraft and reduce landing distance.
640 – 10. Increase lift, increase drag.
640 – 11. Under the trailing edge of the wings.
640 – 12. Elevators.
640 – 13. Trim tab on the elevators.
640 – 14. Movable horizontal stabilizer.

641 – 1. Artificial feel system.
641 – 2. No.
641 – 3. Electrical trim system.
641 – 4. Stability augmentation (stab aug) and autopilot (A/P).
641 – 5. Used to make the aircraft a stable platform from which weapons can be launched.
641 – 6. Used for pilot relief (to fly the aircraft along a predetermined course selected by the pilot).

642 – 1. (1) e.
(2) g.
(3) i.
(4) b.
(5) j.
(6) f.
(7) d.
(8) h.
(9) a.
(10) c.

643 – 1. Hydraulic.
643 – 2. To control the flow of hydraulic pressure into the system.
643 – 3. Through a servomotor.
643 – 4. To prevent damage to the rudder supporting structure.
643 – 5. By placing the rudder switches to ON.
643 – 6. By a switch on the wing flaps.
643 – 7. Through mechanical force.
643 – 8. The rudder boost system shutoff valves were closed.
643 – 9. Energized.

644 – 1. Mechanically and hydraulically.
644 – 2. If one side became jammed, the override spring would deflect under force and allow operation of the other lateral control surfaces.
644 – 3. Yes.
644 – 4. Yes.
644 – 5. Yes. The feel selector valve is energized, letting hydraulic fluid actuate feel cylinder piston.
644 – 6. Aileron control valves and spoiler servo valves.
644 – 7. Stability augmentation (stab aug) and autopilot (A/P).
644 – 8. Double action spring cartridges connected in tandem with screw jack actuators.
644 – 9. To cause rudder displacement proportional to aileron displacement to provide coordinated turns at low airspeeds.
644 – 10. A dynamic bellows acting through a bob weight and variable bell crank on the trim actuator.
644 – 11. Meters hydraulic fluid to the power cylinder.
644 – 12. Allows the feel and trims portion to be bypassed in the event of noseup trim malfunction.

645 – 1. An unsynchronized condition.
645 – 2. Manually.
645 – 3. Hydraulic disc flap brake.
645 – 4. Solenoid-operated wing flap selector valve.
645 – 5. To the flap motor.

646 – 1. A selector valve; a flow divider and the trailing edge flap actuating cylinder.
646 – 2. It is dumped overboard.
646 – 3. Restrictor valves.
646 – 4. DOWN.
646 – 5. A flow divider and into the down side of the TE flap actuating cylinder.
646 – 6. A selector valve, flow divider, and the LE and TE flap actuating cylinders.

647 – 1. Checking to see that the control surfaces go to the right position when the control device in the cockpit is moved.
647 – 2. Hydraulic test stand and generator set.
647 – 3. Make sure it has been cleared.
647 – 4. These are points where breaks in the cables often take place.
647 – 5. Replace the pulley.
647 – 6. To measure the travel of the control surface.
647 – 7. To ascertain the maximum allowable component leakage rate.
647 – 8. No. Most templates are made for particular aircraft.

648 – 1. The applicable aircraft organizational maintenance manual.
648 – 2. Check for proper operation.
648 – 3. To prevent cross-connection during installation.
648 – 4. Shop capabilities and -6 TO limitations.
648 – 5. Read each step of the technical order individually.
648 – 6. Cap the lines and hoses.

649 – 1. A test box.
649 – 2. Loose or worn linkage.
649 – 3. You should check the trim switch in the rear cockpit. This will tell you whether or not the trim switch in the front cockpit is bad or something else in the system is bad.
649 – 4. The flow divider has malfunctioned.
649 – 5. Solenoid "A" only.

650 – 1. The crank is improperly adjusted.
650 – 2. Bleed the cylinder of air.
650 – 3. By measuring the leakage in a graduated cylinder.
650 – 4. The servo valve must be replaced.

651 – 1. Screw the rod end into the piston.
651 – 2. For nondestructive testing.
651 – 3. Screw end onto barrel until it bottoms, then back a maximum of one turn to align the ports.
651 – 4. The bearing will have to be staked.
651 – 5. It should be polished out with crocus cloth.
651 – 6. From the centerline of the rod end bearing and the cylinder barrel mounting holes.

CHAPTER 5

652 – 1. The air compressor would not be lubricated properly and may be damaged.
652 – 2. Air regulator.
652 – 3. Leakage will come out the drain on the access door.
652 – 4. The thermostat heating blanket.
652 – 5. Air servicing valve, filter, and direct reading pressure gage.

652 – 6. A filter in the dump valve port.
652 – 7. The hydraulic control valve and the dump valve solenoid.

653 – 1. Sequence valves.
653 – 2. It is vented overboard.
653 – 3. For emergency use such as hydraulic pressure and electrical power.
653 – 4. Pressure in the OUT lines.
653 – 5. OPEN position.
653 – 6. To prevent the system from being depleted in case the basic pneumatic system should fail.

654 – 1. The selector valve is bad or a wire is broken.
654 – 2. An external leak or the dump valve inoperative.
654 – 3. Door sequence valve.
654 – 4. Ram air turbine actuator, because the door sequence valve will prevent any leakage from the door actuating cylinder from reaching the vent port of the selector valve.

655 – 1. Bubbles from the tube appear in the water if the valve is not closing properly.
655 – 2. The pressure switch contact points are open.
655 – 3. By connecting an ohmmeter to the electrical connections on the heater while flexing the blanket. This will indicate whether or not an open exists in the circuitry.
655 – 4. By forcing air through the inlet port and checking for bubbles at the outlet port. The bubbles should form at the proper pressure setting.
655 – 5. The solenoid-operated dump valve must be inoperative. The reason is that, if the light is on, the dump valve should be closed.

656 – 1. By the fluorescent penetrant inspection method.
656 – 2. Inlet port.
656 – 3. If the valve should rupture during testing, it could cause injury to personnel.
656 – 4. With pneumatic pressure applied to the outlet port, depress the plunger and check for air flow from the inlet port.

CHAPTER 6

657 – 1. (1) b.
(2) c.
(3) a.
(4) c.
(5) b and c.

658 – 1. Ring spring assembly.
658 – 2. Surge boot.
658 – 3. They center and support the inner structural tube.
658 – 4. Motor-driven sprocket and chain assembly.
658 – 5. Gland seals.

659 – 1. The pilot director light will indicate the position to the receiver pilot.
659 – 2. By the markings on the boom.
659 – 3. The pilot should increase the altitude and decrease the airspeed.
659 – 4. No. There are no lights to indicate asimuth position of the boom.

660 – 1. By gravity flow.
660 – 2. In the forward and aft body tanks.
660 – 3. By the manual override handle on the line valve.
660 – 4. The hydraulic shutoff valve must be energized. When this happens hydraulic pressure is available to operate the hydraulic motors.
660 – 5. It senses the fuel flow through the boom.
660 – 6. The fuel bypass valve.
660 – 7. Fuel bypass control valve.

661 – 1. Boom hoist, tension motor, and ruddevators.
661 – 2. a. Boom operators sighting door.
b. Boom hoist
c. Boom telescope.
d. Fuel bypass.
e. Fuel dump.
f. Ruddevators.
661 – 3. The fuel dump actuator pushes the check valve in the nozzle, which allows the fuel to be dumped.
661 – 4. The bypass valve will dump the fuel pressure into the aft body tank when the boom is placed in the retract position.
661 – 5. To all the hydraulic subsystems.
661 – 6. The ruddevators are used to fly the boom.
661 – 7. It positions the control valve on the ruddevator power unit.
661 – 8. The tension motor drives a drum, which takes up the slack in the boom hoist cable.
661 – 9. In the LOWER position.

662 – 1. Through the signal coils in the nozzle and receiver receptacle.
662 – 2. READY.
662 – 3. A signal will be sent to the amplifier which will automatically cause a disconnect.
662 – 4. Within 7 inches of full retract.
662 – 5. a. By the boom operator's disconnect switch.
b. When the receiver aircraft exceeds the envelope limits.
c. Actuation of a disconnect signal through the signal coil.

663 – 1. a. Fuel system.
b. Hydraulic system.
c. Electrical system.
663 – 2. 4-inch fuel tube.
663 – 3. Because of the larger area on the open side of the piston.
663 – 4. The relief valve will bypass fluid down the retract side if pressure becomes excessive on the pullaway of the air refueling nozzle from the receptacle.
663 – 5. READY, CONTACT (MADE), and DISCONNECT.
663 – 6. The door CLOSED AND LOCKED light will go out.
663 – 7. a. Actuation of the autopilot ARR disengage button.
b. Actuation of a disconnect signal by the tanker boom operator.
c. Excessive fuel pressure.
d. A break in contact between the tanker and receiver aircraft.
e. When the receiver aircraft exceeds the envelope limits.
663 – 8. The reset button must be placed to the RESET position. This momentarily drops power to the amplifier.

664 – 1. So the stand and boom are not damaged.
664 – 2. The accumulator would only require a pressure check. You should only perform the necessary steps to insure that the component is operating properly.
664 – 3. Because of the dangerous voltage that may be induced into the boom.
664 – 4. To insure the proper amount of force in order to move the ruddevator control stick.

665 – 1. Leaking or chaffed hoses.
665 – 2. If the hydraulic pressure is not depleted, the boom may be accidently extended, and injury to personnel and equipment could result.
665 – 3. For damage, binding, and proper operation.
665 – 4. To prevent dirt or contamination from entering the system.

666 – 1. Either the sighting door control valve or the mechanical lock in the actuator is out of adjustment.
666 – 2. The sighting door control valve improperly positioned, or the boom hoist control valve linkage out of adjustment.
666 – 3. The manual shutoff valve improperly positioned.
666 – 4. Check the signal amplifier circuit breaker first.
666 – 5. The signal coil has been known to corrode and cause this problem. The remedy is to remove the corrosion on the signal coil.
666 – 6. The accumulator; it should be properly serviced.

667 – 1. Care should be taken to prevent damage to the threads of the nozzle.
667 – 2. By rolling the spring to see if it wobbles and by subjecting the spring to a compression test.
667 – 3. By swabbing the components with a copper sulphate solution. Areas that are worn through will show a visible copper coating.
667 – 4. When a compass is held against the coil, the needle will point in the wrong direction.
667 – 5. 30 seconds.
667 – 6. It should return to the CLOSED position without hesitation or evidence of sticking or binding.

668 – 1. Low voltage and sensitivity test.
668 – 2. The green lights should be on.

668 – 3. Insure that the electrical power source is connected to the proper terminals on top of the test box.
668 – 4. By hooking the amplifier to the test box with the electrical cable which extends from the side of the box.
668 – 5. Signal position.

CHAPTER 7

669 – 1. The selector valve directs fluid to the door actuator.
669 – 2. ARM.
669 – 3. ARM.
669 – 4. The pressure door actuator selector valve would not otherwise energize.
669 – 5. When the aircraft is on the ground.

670 – 1. OPEN.
670 – 2. Open relay then close relay.
670 – 3. 80°.
670 – 4. 80° limit switch.
670 – 5. Hydraulic motor, jackscrew and torque tube arrangement.

671 – 1. All door.
671 – 2. Pressure door.
671 – 3. Ramp stop links.
671 – 4. Stop.
671 – 5. Open.

672 – 1. CLOSE or DOWN position.
672 – 2. For maintenance purposes when electrical power is not available.
672 – 3. Uplock selector valve.
672 – 4. Pressure for the unlock actuator is not available.

673 – 1. Petal door selector valve and the door lock selector valve.
673 – 2. Petal door selector valve.
673 – 3. 55°.
673 – 4. Door selector valve is depressed.

674 – 1. Step 2.
674 – 2. Door selector valve.
674 – 3. These selector valves direct fluid to the ramp actuators and lock actuators.
674 – 4. From the uplock actuators of the pressure door selector valve.
674 – 5. Depress the lock selector valve.

675 – 1. Used to test the circuit for the doors and assist in troubleshooting.
675 – 2. Insufficient hydraulic pressures at the selector valves.
675 – 3. To remate the sequence switches to the all door control panel.
675 – 4. Doors improperly sequenced.
675 – 5. Using the manual selector valves individually may cause the doors to operate out of sequence.

676 – 1. A fluid cooler.
676 – 2. An orifice check valve.
676 – 3. The top envelope must be placed in the center position. As you can see, this will direct fluid to the top line of the actuator, thus retracting the cylinder.
676 – 4. This indicates an orifice check valve.
676 – 5. It can be rotated in either direction.
676 – 6. A variable volume pump.

677 – 1. T.
677 – 2. F. Static pressure is built up by the hydraulic booster.
677 – 3. T.
677 – 4. T.
677 – 5. T.
677 – 6. F. The fluid for pump testing is delivered to parts 54 and 54A from the boost pump (11).
677 – 7. F. Inlet 66 is for shop air.
677 – 8. (1) d.
(2) c.
(3) b.
(4) a.
(5) e.
(6) g.
(7) f.
(8) c.

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